This document is guaranteed to be current only to issue date.

Some Mars Global Surveyor documents that relate to flight operations are under revision to accommodate the recently modified mission plan.

Documents that describe the attributes of the MGS spacecraft are generally up-to-date.

542-409, Vol. 2

MARS GLOBAL SURVEYOR

MISSION OPERATIONS SPECIFICATION

VOLUME 2

DATA SYSTEM

Final

May 19, 1995

Jet Propulsion Laboratory
California Institute of Technology

JPL D-12369, Vol. 2

542-409

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VOLUME 2

DATA SYSTEM

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May 19, 1995

Prepared by:

Richard D. Benson

Richard D. Benson
Ground Data System Engineer
Mars Global Surveyor Project

Approved:

S. Sam Dallas

S. Sam Dallas
Mission Manager
Mars Global Surveyor Project

Concurred:

Fred J. Hammer

Fred J. Hammer
Ground Data System Lead
Mars Global Surveyor Project

Reviewed:

M. J. Alazard

Marius J. Alazard
Mission Operations Support Office
Manager for Mars Global Surveyor

Reviewed:

Marvin Traxler

Marvin R. Traxler
Tracking and Data Systems Manager
for Mars Global Surveyor

JPL

Jet Propulsion Laboratory
California Institute of Technology

JPL D-12369

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M Witkowski	301-331

Dr. Mario H. Acuna
Laboratory for Exterrestrial Physics
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

Dr. Donald Anderson
Department of Geology
Arizona State University
Tempe, AZ 85287

Dr. Raymond E. Arvidson
McDonnell Center
Department of Earth/
Planetary Sciences
Washington University
St. Louis, MGS 63130

Dr. William V. Boynton
Department of Planetary Sciences
Lunar and Planetary Laboratory
University of Arizona
Tucson, AZ 85721

Dr. Michael Caplinger
1011 Camino Del Rio South
Suite 210
San Diego, CA 92108

Dr. Michael H. Carr
U.S. Geological Survey
M/S 946
345 Middlefield Road
Menlo Park, CA 94025

Dr. Philip R. Christensen
Department of Geology
Arizona State University
Tempe, AZ 85787

Dr. David W. Hancock, III
Observational Science Branch
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA 23337

Dr. Bruce M. Jakosky
Laboratory for Atmospheric and
Space Physics
University of Colorado
Boulder, CO 80309

Dr. David E. Smith
Geodynamics Branch
Goddard Space Flight Center
Greenbelt, MD 20771

Dr. Laurence Soderblom
U. S. Geological Survey Office
of Regional Geology Branch of
Astrogeology
2255 N. Gemini Drive
Flagstaff, AZ 86001

Dr. Leonard G. Tyler
Center for Radar Astronomy
Stanford University
Stanford, CA 94305

Dr. Michael C. Malin
1011 Camino Del Rio South
Suite 210
San Diego, CA 92108

Mr. Richard McCloskey
Lunar and Planetary Laboratory
University of Arizona
Tucson, Az 85721

Mr. E. Thomas Northam
Observational Science Branch
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA 23337

Dr. James B. Pollack
M/S 245-3
Space Sciences Division
NASA Ames Research Center
Moffett Field, CA 94035

Dr. Richard Simpson
Center for Radar Astronomy
Standford University
Standard, CA 94305

Mr. Thurston Carleton
Goddard Space Flight Center
Code 694
Greenbelt, MD 20771

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ABBREVIATIONS AND ACRONYMS

AACS	Attitude and Articulation Control System
ACT	Automated Command Tracker (Toolkit & Database)
ABM	Aero Braking Maneuver
AMMOS	Advanced Multimission Operations System
ANSI	American National Standards Institute
ARS	Astronomical Reference System
ASTD	ASCII Spacecraft Tracking Data file
ATDF	Archival Tracking Data File
ATHENA	A Theoretical Evaluation of Navigation Accuracy
ATM	Mars Atmospheric Density Error Evaluation
BCE	Bench Checkout Equipment
CCP	Central Communications Processor (DSN)
CDROM	Compact Disk Read Only Memory
CMD	Command
CMD_DSN	MGDS Command System to DSN iterface file (also known as GCMD)
CRS	Celestial Reference Set
CTA-21	Compatibility Test Area (older designation, now DTF-21)
D	Development phase of MOS capabilities
DAC	Data Acquisition and Command Subsystem
DBA	Database Administrator
DE	Development Ephemeris
DL	Decommuntation Language
DMD	Data Monitor and Display
DMR	Detailed Misson Requirements
DN	Data Number
DOD	Differential One-way Doppler
DOR	Differenced One-way Ranging
DP	Data Products
DPTRAJ	Double Precision Trajectory Program Set
DSCC	Deep Space Communications Complex
DSN	Deep Space Network
DSNOT	DSN Operations Team
DSP-R	DSCC Spectrum Processor - Radio Science
DSR	Data Storage and Retrieval Subsystem
DSS	Deep Space Station (DSN Station)
DTF	Development Test Facility (of DSN)
DTM	Digital Terrain Model
DTR	Digital Tape Recorders
DTS	Data Transfer Subsystem
E	Encounter phase of MOS capabilities
EAS	Engineering Analysis Subsystem
EDR	Experiment Data Record
EMOC	Extended Mars Global Surveyor Community
EOM	End-of-Mission
ERT	Earth Receive Time
ETR	Eastern Test Range
EU	Engineering Units
FAST	Fast Trajectory Analysis Program Set
FOV	Field of View

GCMD	Ground Command File (older name for CMDSYS to DSN i/f; aka CMD_DSN)
GCO	Gravity Calibration Orbit
GIF	Ground Communications Facility Interface
GIN	Navigation Constants File
GRS	Gamma Ray Spectrometer (MO instrument, not part of MGS)
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HIPO	Heirarchical Input, Processing, Output diagram
ICD	Interface Control Document
IDR	Intermediate Data Record
IDS	Interdisciplinary Scientist
IFOV	Instrument Field-of-View
IPC	Information Processing Center
ISOE	Integrated Sequence of Events
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
L	Launch phase of MOS capabilities
LAN	Local Area Network
LAMBO	TBS by Nav
LAMBIC	TBS by Nav
LDB	Local Data Base
LITIME	Light Time File
LUE	Launch Unique Element
LR-MDIM	Low Resolution Mosaic Digital Image Model
M&C	Monitor and Control
MAG	Magnetometer
MCT	Mission Control Team
MDA	Metric Data Assembly (@ DSS)
MDR	Master Data Record
MDRGen	Master Data Record Generation
MGDS	Multimission Ground Data System
MMCT	Multimission Control Team
MMET	Multi-Mission Ephemeris Team
MOAT	Mission Operations Assurance Team
MOC	Mars Orbiter Camera
MOI	Mars Orbit Insertion
MOLA	Mars Orbiter Laser Altimeter
MON	Monitor (DSN) Data
MOPS	Maneuver Operations Program Set
MOS	Mission Operations System
MOSO	Mission Operations Support Organization
MPSA	MOSO-Project Support Agreement
MRD	Mission Requirements Document
MRR	Mission Requirements Request
MSFC	Marshall Space Flight Center
MSP	Mission Sequence Plan
MSP	Mars Surveyor Program
MST	Monitor Sample Time
MSTP	Mission Software Transition Project
MTBF	Mean Time Between Failure
MTTR	Mean Time to Restore

NAS	Navigation Analysis Subsystem
NAV	Navigation team or activity; also Navigation subsystem at DSN NOCC
NAVINFO	Navigation program
NAIF	Navigation Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications
NAVIO	Navigation Input/Output Format
NCF	Navigation Computing Facility
NOCC	Network Operation Control Center
OCM	Orbit Change Maneuver
ODF	Orbit Data File
ODR	Original Data Record
ODS	Original Data Stream
ODP	Orbit Determination Program
OPTG	Orbit Propagation and Timing Geometry
OTM	Orbit Trim Maneuver
OWLT	One-Way-Light Time File
PCM	Planetary Constants and Models
PDB	Project Data Base
PDS	Payload Data Subsystem
PDS	Planetary Data System
PEF	Predicted Events File
PET	Probe Ephemeris Tape
PI	Principle Investigator
PMIRR	Pressure Modulator Infrared Radiometer (MO instrument, not on MGS)
PR/MSP	Project Requirements/MOSO Support Plan
PSA	Pack, Solve and Analyze
PSS	Planning and Sequencing Subsystem
PV	Spacecraft Ephemeris and Partial Derivative File
QQC	Quantity, Quality and Continuity
R/M	Radiometric (Data)
R/T	Real Time
RA	Radar Altimeter
RAM	Random Access Memory
RCF	Real Time Command File
RCT	Record creation time
RDC	Radiometric Data Conditioning
RF	Radio Frequency
RICF	Realtime Interactive Command File
RIRF	Realtime Interactive (Command) Request File
RM	Radiometric
RNCF	Realtime Non-interactive Command File
RNRF	Realtime Non-interactive (Command) Request File
ROM	Read Only Memory
RRF	Real Time Command Request File
RS	Radio Science
RSST	Radio Science Support Team
S/C	Spacecraft
SSS	Science Analysis Subsystem
SCET	Spacecraft Event Time (on-board event time; SCLK translated to UT format)
SCLK	Spacecraft Clock (on-board counter)
SCMF	Spacecraft Message File
SCP	Station Communications Processor (DSN)

SCP	Status, configuration, and performance (Radio Science data type)
SCT	Spacecraft Team
SDP	Standard Data Product
SEPV	(TBS - NAS)
SFDU	Standard Formatted Data Unit
SIM	Simulation or Simulated
SIS	Software Interface Specification
SIT	Science Investigation Team
SOA	Sequence of Activities
SOE	Sequence of Events
SOPC	Science Operations Planning Computer
SPA-R	Spectrum Processing Assembly - Radio Science
SPICE	S/C, Planetary, Instrument, S/C Reconstruction & Event database
SRD	Science Requirements Document
SRF	Sequence Request File
SSI	Signal Spectral Indicator
SSS	Science Support Subsystem
SSF	Stored Sequence File
STATRJ	Station Polynomial Coefficients File
STOIC	Standby Timing Operation in Contingencies
TBD	To Be Determined
TES	Thermal Emission Spectrometer
TL	Team Leader (Science Teams)
TLO	Transfer to Low Orbit
TLM	Telemetry
TMO	Transfer to Mapping Orbit
TRK	Tracking
TRM	Transit Time
TSAC	Tracking System Analytical Calibrations
USGS	United States Geological Survey
USO	Ultra-Stable Oscillator
UTC	Universal Time Coordinated
VLBI	Very-long Baseline Interferometry (n.a. for MGS)
VOCA	Voice Operational Communication Assembly
WCSC	West Coast Switch Center
WORM	Write-Once-Read-Many Optical Media

1.0 INTRODUCTION

This Data System specification will define all hardware, software, networks, and data system user documentation needed for ground support of Mars Global Surveyor (MGS) flight operations, preflight system testing, and operations training. Data System components are provided by the Deep Space Network (DSN), the Mission Operations Support Office (MOSO), the spacecraft contractor (Martin Marietta Astronautics), the Project scientific investigators, and the MGS Project (in some cases via the JPL Technical Divisions or commercial vendors). Additionally, all interfacing systems with the MGS Ground Data System (GDS) will be described herein to the extent necessary to provide the context in which the GDS will be designed and operated. This is not the controlling document for the requirements on the external systems, only on the interfaces between the external systems and the MGS Data System.

The purpose of this specification is to allocate functional requirements, performance requirements (performance of hardware and software only, operational performance requirements are covered in Volume 3: Operations), interface requirements, and hardware/network requirements to each of the GDS Subsystems and the interface requirements to the external systems. Additionally, for each of the GDS Subsystems, the functional requirements are further sub-allocated within each Subsystem to the extent necessary to provide a coherent design of the overall GDS.

The Ground Data System development approach is driven by a few MGS Project guidelines which are summarized below:

1) Use Mars Observer (MO) data system and operational inheritance where possible to reduce development costs.

2) Maintain compatability with the JPL Advanced Multi-Mission Operations System (AMMOS) 4.3 baseline for the duration of mission operations. The main intent of AMMOS 4.3 compatability is to avoid migration to new operating system or hardware platform environments during the course of mission operations.

3) Use automation, including "enabling technologies", to simplify operations; use shared operations; use multimission support where possible.

4) Produce a system which can be operated and maintained for 60% of the equivalent MO levels.

The Mars Global Surveyor Data System is being developed in three phases as listed below. This release of Volume 2 contains draft requirements for all three phases.

D Development Phase to support spacecraft development and pre-Launch Flight Sequence development.

L Launch Phase to support MOS-Spacecraft compatability testing, launch operations, and cruise operations through Mars Orbit Insertion (MOI) minus 90 days.

E Encounter Phase to support MOI and Orbital Operations through End-of-mission.

Liens

Four aspects of the MGS GDS preliminary design were listed as liens in the preliminary version of this document (dated December 16, 1994) and are resolved in this final version as follows:

1. E Kernel implementation - The Project Mission Operations Assurance Team (MOAT) will produce E kernels as described in Volume 3, section 3.6.2 and using the software described in this volume, section 4.6.4.3.1.

2. Validate, Recall, and Merge - Until the DSN advanced delivery system is operational in June 1997, the project MOAT will validate telemetry data as described in Volume 3, section 3.6.2 and recall data from the DSN central data recorder, and merge data streams for level-0 record production. Tools retained from MO and described in this volume, section 4.6.4.3.2 are available. After June 1997, that MOAT task will reduce to validation incidental to the project database administration task - recall and merge will no longer be required at the project level.

3. E-mail - will be supported; the issue of a mail server *per se* will be resolved before the Mission System CDR.

4. Long loop simulation is no longer available. The TMOD Combined Test Team has modified their system testing strategies and procedures to use pre-arranged simulation data sets and are committed to comprehensive testing and system delivery on that basis.

2.0 APPLICABLE DOCUMENTS

The latest issues of the following documents are directly applicable to and furnish source requirements for this document.

542-303	Mars Global Surveyor Investigation Description and Science Requirements Document
542-400	Mars Global Surveyor Mission Requirements Document
542-422	Mars Global Surveyor Mission Requirements Request
JPL D-12268	Mars Global Surveyor MOSO-Project Support Agreement
542-403	Mars Global Surveyor Project Data Management Plan
542-409	Mars Global Surveyor Mission Operations Specification, Vol. 1, System
542-311	Mars Global Surveyor Payload Operations Facility Configuration and Control Plan

The following documents respond to this document:

MOSO-0033-02-00 (5/19/93)	Project Requirements/MOSO Support Plan (PR/MSP) for Mars Observer (Memo update for MGS)
542-424	DSN Detailed Mission Requirements (DMR) for Mars Global Surveyor

Related Documents:

542-200 Mars Global Surveyor Spacecraft Requirements

542-409 Mars Global Surveyor Mission Operations Specification:

- Vol 3 Operations
- Vol 4 Procedures
- Vol 5 Interfaces
  - Software Interface Specifications
  - Operational Interface Agreements
- Vol 6 Test
- Vol 7 Training
- Vol 8 Facilities
- Vol 9 Handbooks
- Vol 10 Flight Rules
- Vol 11 Contingency Plans
- Vol 12 Flight Software

542- 407 Mission Sequence Plan

542-404 MGS Project Security Plan

3.0 DATA SYSTEM

The MGS Data System shall perform the following functions:

a) Accept MGS spacecraft (S/C) and Spacecraft Test Laboratory (STL) telemetry (realtime, spacecraft playback or DSN replay), radio science, and monitor data and process it into various forms, including:

    1) Real-time displays of S/C Engineering, Instrument Housekeeping, and ground data system monitor and control for system performance monitoring purposes.

    2) Intermediate telemetry products (frames, packets, channels, etc.), for delivery to engineering & science teams.

    3) Ancillary data products for use by the science teams in analysis and archiving of the science data.

b) Accept and process and display radiometric data to determine the S/C trajectory.

c) Develop, validate, and uplink (i.e., send to the S/C) integrated sequences of commands to accomplish the following:

    1) Science observations, including Radio Science.

    2) Trajectory control per the Mission Sequence Plan.

    3) Engineering operations and calibrations.

    4) Science calibrations.

d) Develop, validate and uplink real-time science commands.

e) Develop, validate and uplink real-time engineering commands for S/C operations, health and safety.

f) Provide tools for analysis of spacecraft engineering data.

g) Provide tools to assist scientists in instrument monitoring.

h) Provide storage and retrieval of all products required for (a) to (g).

3.1 DATA SYSTEM SUPPORT CONFIGURATIONS

3.1.1 Spacecraft Test Support Configuration

During this support phase the spacecraft is at the spacecraft system contractor's site. This Data System configuration supports S/C system testing and development of the Mission Operations System. As shown in Figure 3.1, the major data paths carry telemetry data from either:

1) The spacecraft and Spacecraft Checkout Station (SCS),

-or-

2) The Spacecraft Test Lab (STL),

to a MOSO Test Telemetry and Command Subsystem (TTACS), then via network/data line (NASCOM link) to the normal MGDS and Project data paths. The Spacecraft Checkout Station is an ensemble of ground support equipment (GSE) and interface equipment. As a backup to the network/data line, spacecraft data files, generated by the Spacecraft/SCS or STL, may be used as input to the MGDS Simulation system.

The command data path from the Project operational support area (OSA) to the spacecraft/SCS or STL is via file transfer over the network to the TTACS. The STL is capable of converting the command file to a bit stream. For spacecraft/SCS commanding, TTACS converts the command file to a command bit stream.

3.1.2 Payload Processing Facility Support Configuration (S/C at KSC)

During this phase, the spacecraft is in the Payload Processing Facility at the Eastern Launch Site (Cape). This Data System configuration supports final S/C system testing and Mission Operations System/spacecraft compatability testing. As shown in Figure 3.2, two telemetry data paths exist in this configuration.; the first path is via TTACS, NASCOM, and MGDS as in 3.1.1. The second path is an RF link between the spacecraft and the DSN's Merritt Island facility (MIL-71) that can carry telemetry and command data. The RF path will be used to validate the spacecraft-to-MOS and DSN interface. During hazardous activities, only telemetry data flow, primarily through the spacecraft ground support equipment, will occur.

3.1.3 Launch Pad Support Configuration

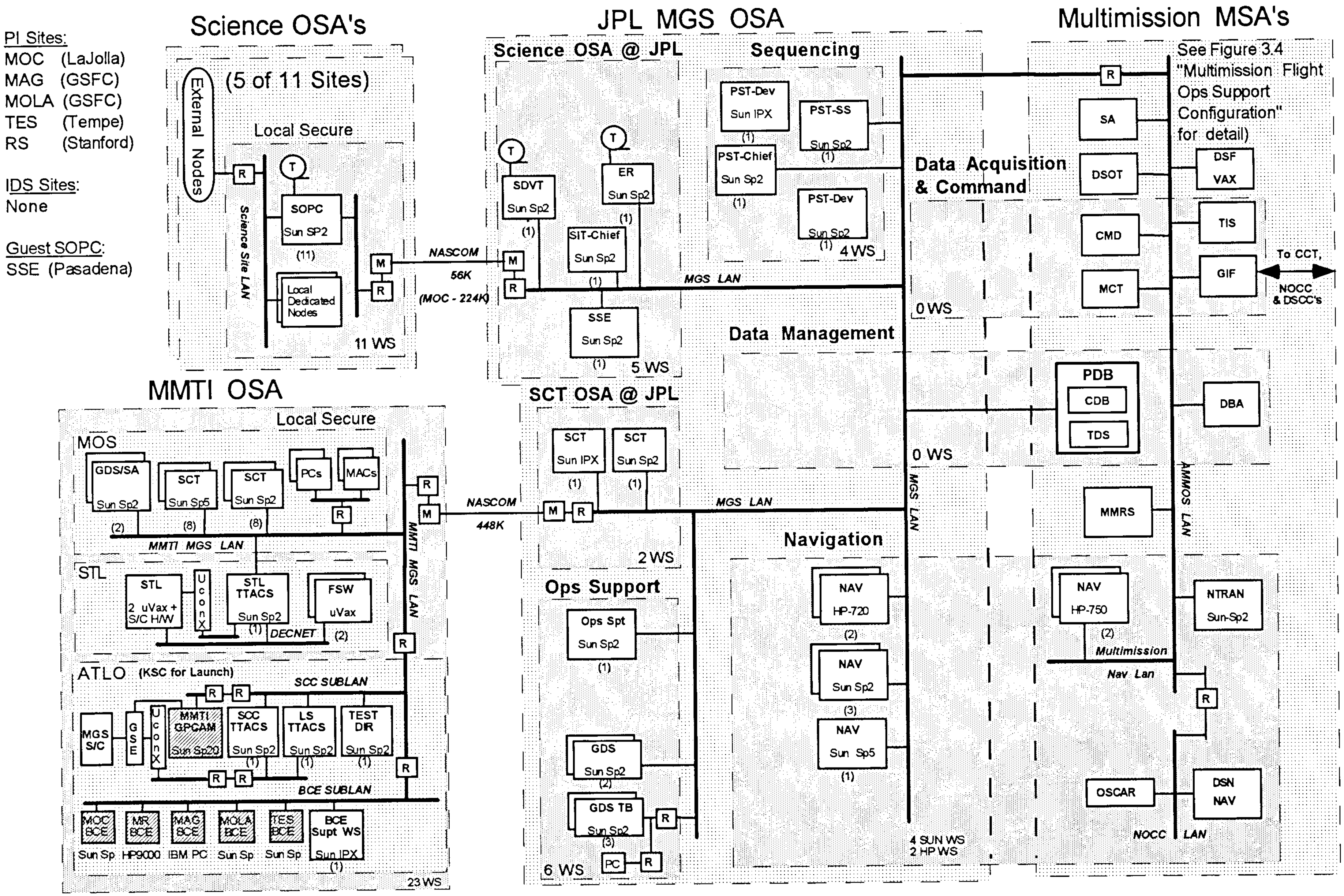
The Launch Pad support configuration is also depicted in Figure 3.2. This Data System configuration supports the S/C during prelaunch activities up to liftoff of the launch vehicle. During this support phase, the spacecraft is at the launch pad. For mission operations this represents a quiescent or monitoring state; the control (command as required) occurs from the spacecraft ground support equipment. Limited spacecraft bus engineering data flows to the project OSA.

3.1.4 Flight Operations Support Configuration

The Flight Operations support configuration is depicted in Figures 3.3 and 3.4. This Data System configuration supports MOS test and training activities, normal flight operations, and GDS maintenance. DSN stations provide the telemetry, tracking and command interface to the project via NASCOM circuits and the MGDS. Following launch, state vector data will be processed at the Delta launch vehicle POCC and forwarded to JPL/DSN/MGDS/OSA.

Figure 3.1 Spacecraft Test Support Configuration (7/1/95)

MGS WS Total: 55 Sun
2 HP



- Non-GFP Eqt.

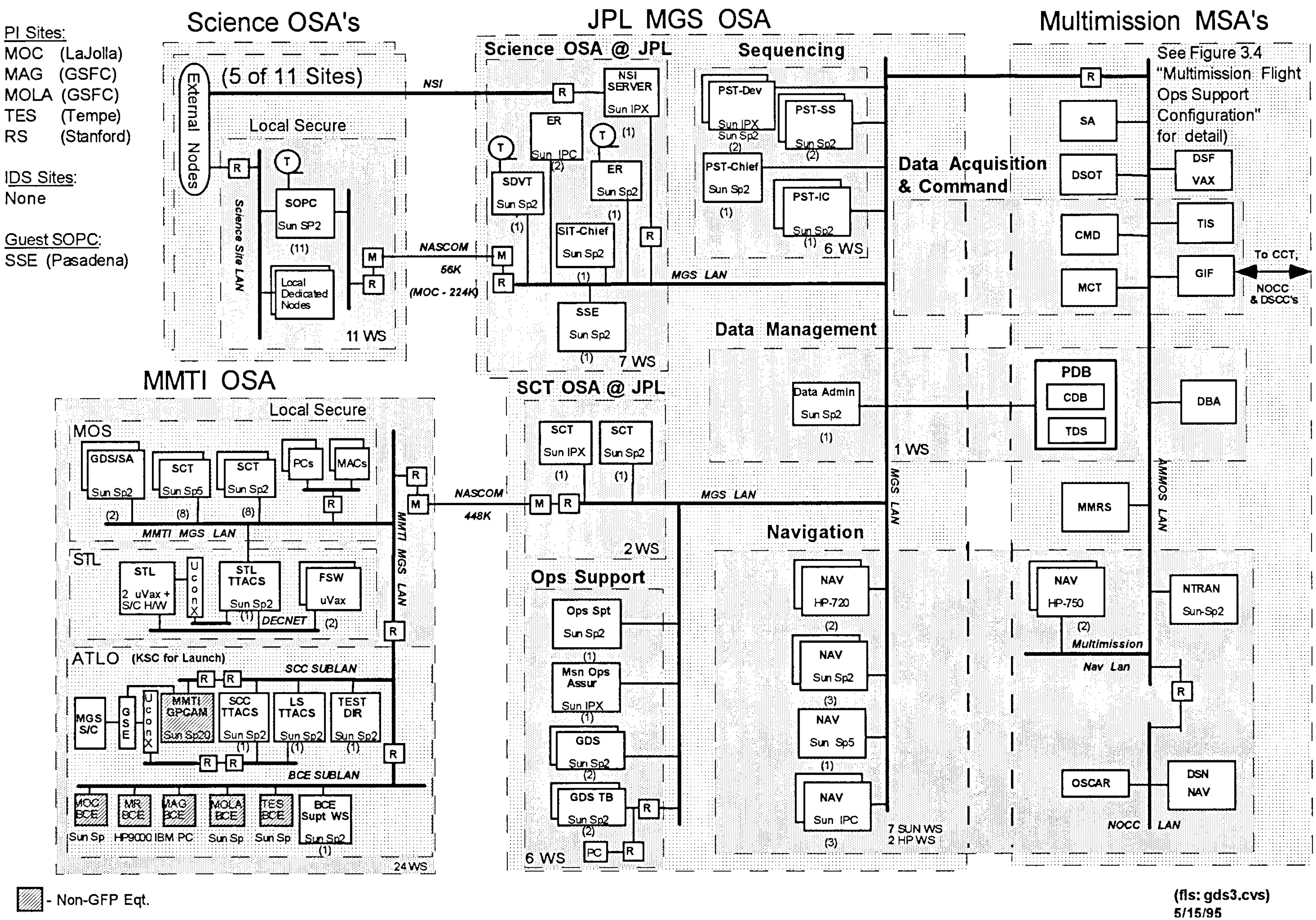
(fls: gds2.cvs)
5/15/95

MARS GLOBAL SURVEYOR

Figure 3.2A Launch Support Configuration (S/C at Denver)

(10/1/95)

MGS WS Total: 63 Sun
2 HP

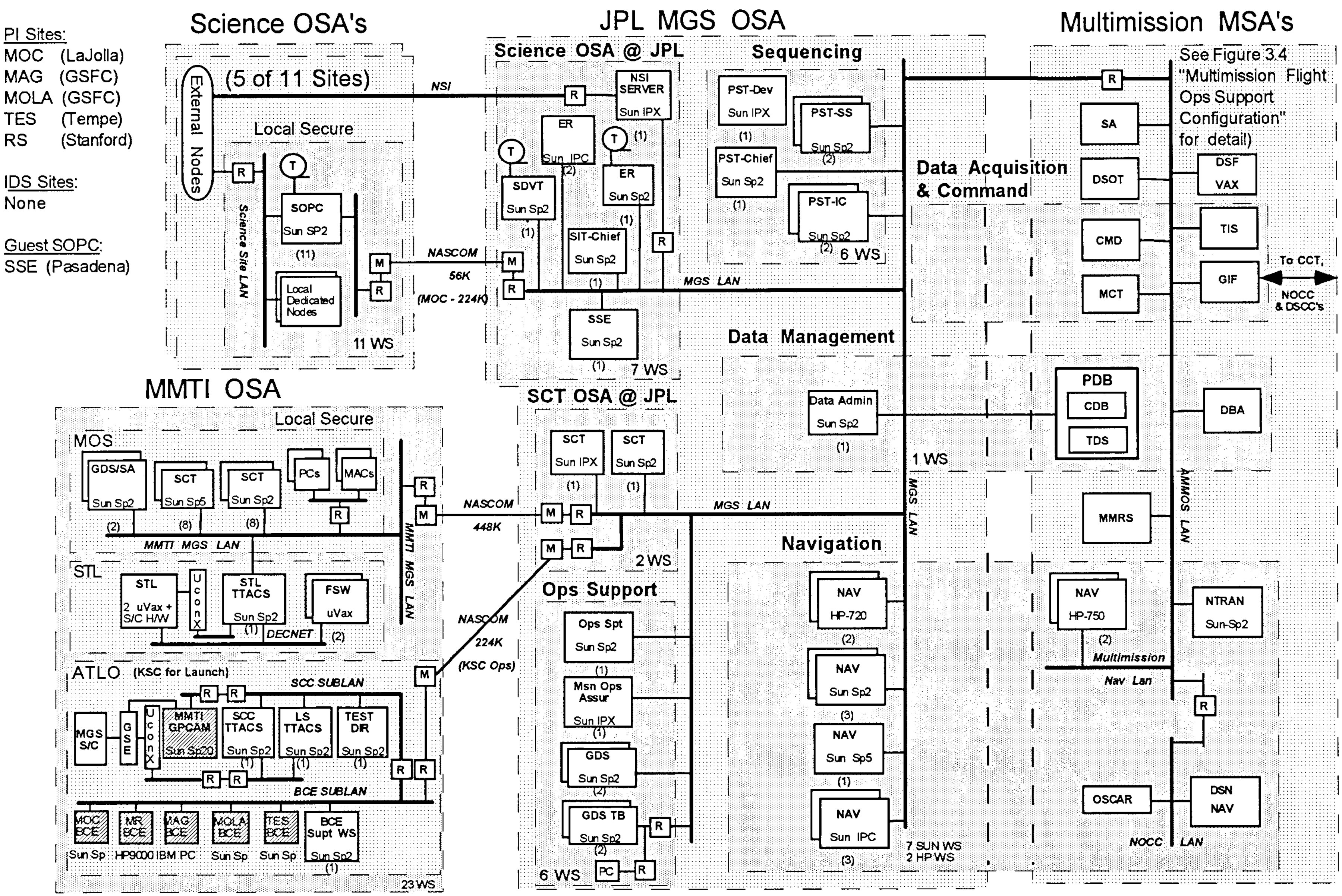


(fls: gds3.cvs)
5/15/95

Figure 3.2B Launch Site Configuration (S/C at KSC - PHSF Opns)

(8-22-96)

MGS WS Total: 63 Sun
2 HP



▨ - Non-GFP Eqt.

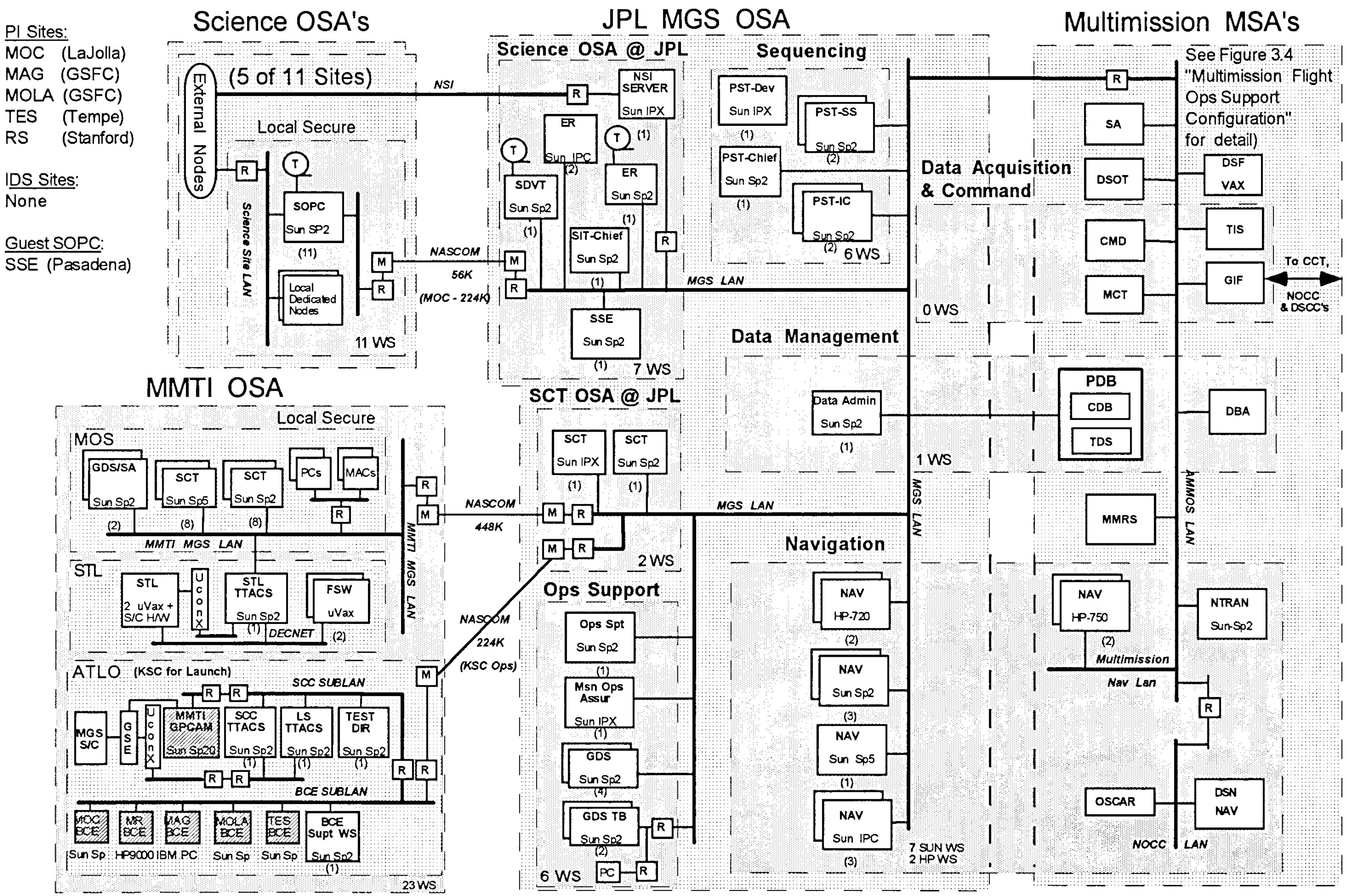
(fls: gds4.cvs)
5/15/95

MARS GLOBAL SURVEYOR

Figure 3.2C Launch Site Configuration (S/C at KSC - Launch Opns)

(10/1/96)

MGS WS Total: 63 Sun
2 HP



- Non-GFP Eqt.

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Figure 3.3 Project Flight Ops Support Configuration

(2/15/97)

MGS WS Total: 58 Sun
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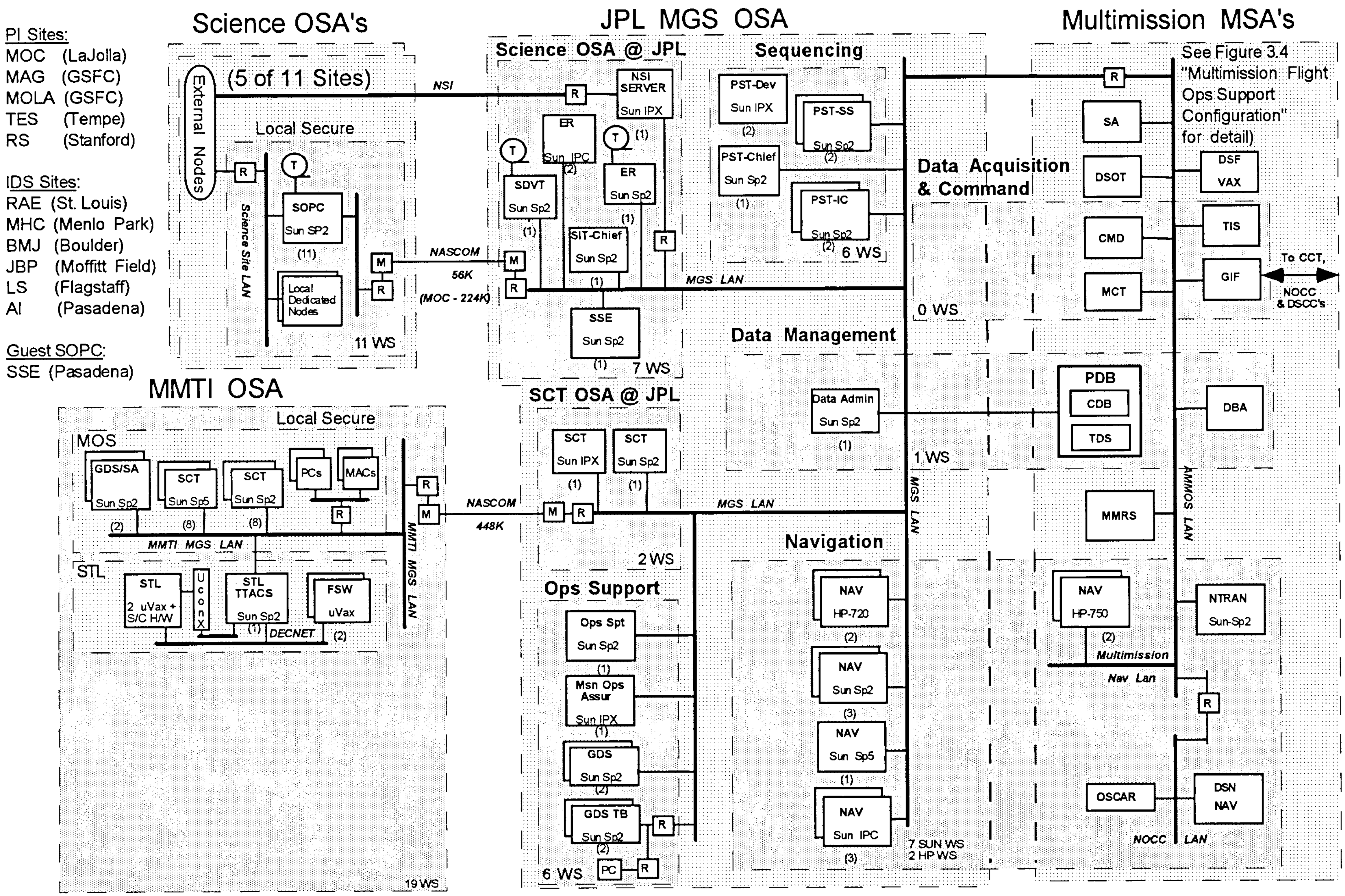

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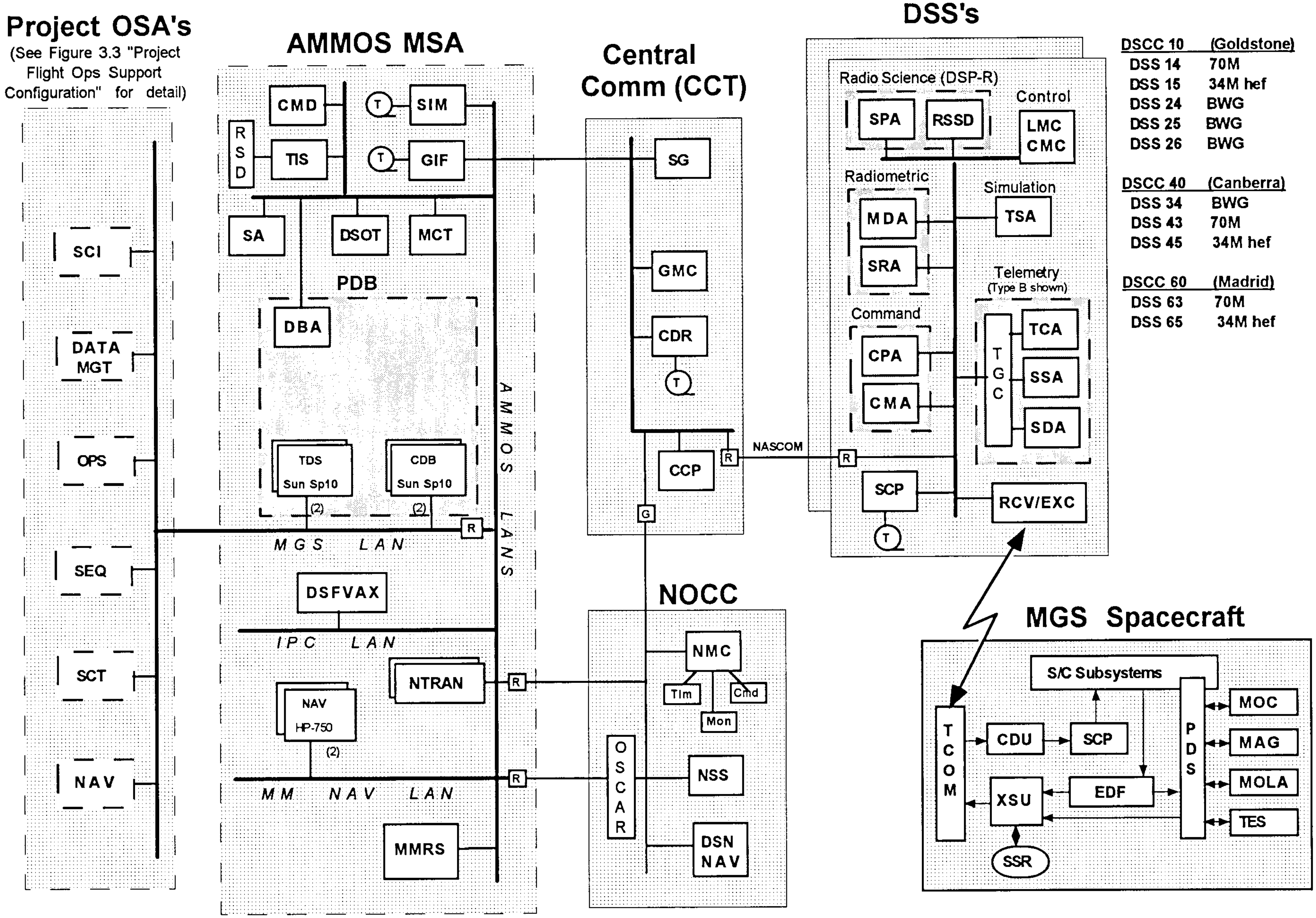
Figure 3.4 Multimission Flight Ops Support Configuration



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5/5/95

The STL will be available to the spacecraft and sequence flight teams for spacecraft and sequence anomaly investigations, sequence testing, capability development and demonstration, and flight software development and verification. Final Science data products will be sent to the Planetary Data System (PDS) by the individual investigation teams.

3.1.5 Data System Support Configuration Components

a) Launch Vehicle

MGS has no requirement for launch vehicle data *per se* or payload (spacecraft) data during the ascent of the launch vehicle. State vector data describing the predicted trajectory of the spacecraft and actual trajectory during ascent will be supplied by the Delta launch vehicle POCC and forwarded to the Project OSAs as in section 3.1.4.

b) Deep Space Network (DSN)

The Deep Space Network facilities can be subdivided as follows:

1) Deep Space Communications Complexes (DSCC's)

Each DSCC includes:

(A) A set of Deep Space Stations (DSS's)

A Deep Space Station is an antenna assembly used to track the MGS Spacecraft for the purpose of acquiring Spacecraft radio frequency signals, and sending commands. Requirements on this facility are found in the Data Acquisition and Command Subsystem.

(B) A Signal Processing Center (SPC)

The SPC is the facility which controls all of the tracking antennas at a DSN site. SPC formats S/C telemetry, radio science and radiometric data for transmission to the NOCC and MGDS. The SPC accepts command traffic from the MGDS for transmission to the S/C. These facilities include the DTF-21 during Spacecraft system testing and MIL-71 for launch testing and operations. Requirements on SPC are found in the Data Acquisition & Command Subsystem.

2) Ground Communications Facility (GCF)

The GCF is the system which physically transfers data between the DSCC's, DSN test facilities, and the NOCC. GCF circuits are also used to support other operational functions such as Communications between MGDS and remote PI facilities. Requirements on this facility are found in the Data Acquisition & Command Subsystem and Science Support Subsystem.

3) Network Operations Control Center (NOCC)

The NOCC is located at JPL. It performs the function of monitor and control of DSN operations, including the DSN complexes.

Requirements on the NOCC are found in the Science Support Subsystem, Planning and Sequencing Subsystem, Navigation Analysis Subsystem, Engineering Analysis Subsystem and Data Acquisition and Command Subsystem. There are 3 major NOCC subsystems

(A) Network Support Subsystem (NSS)

Supports the processing of data from DSCC's into standard products and processing of inputs from flight projects.

(B) NOCC Performance Processor

Supports DSN monitor and control function and provides monitor data to flight projects, as well as accepting network configuration and uplink data.

(C) DSN Navigation Subsystem

Performs functions related to tracking, antenna pointing, etc.

4) Test Facilities

(A) Development and Test Facility (DTF-21)

Located at JPL, DTF-21 performs certain DSCC functions for the purpose of spacecraft/DSN compatibility testing and DSN-MOSO interface testing.

(B) Merritt Island Facility (MIL-71)

Located at KSC, MIL-71 performs certain DSCC functions in conjunction with launch preparations, final spacecraft/DSN compatibility testing, and launch operations.

(C) Compatibility Test Trailer (CTT)

A mobile DCSS. The nominal plan for MGS is to <u>not</u> use the CTT. MGS will conduct initial compatibility testing at DTF-21 with a prototype S/C radio subsystem and final tests at KSC via MIL-71.

c) MGDS Facilities (MOSO provided)

The Multi-Mission GDS (also called AMMOS) facilities provide for data storage, command processing, data transport, engineering telemetry processing into channelized records, and data cataloging functions. Requirements on this facility are found in each of the Ground Data System Subsystems.

d) Navigation Computing Facility (MOSO provided)

Navigation computing software, hardware, and facilities, located at JPL, which provide support to flight projects.

e) Project Operational Support Area

The Project OSA is where project unique functions are performed. Most navigation, planning and sequencing, and engineering analysis are performed here. GDS functional requirements on this facility are found in each of the Ground Data System Subsystems. Actual facility requirements are contained in MGS MOS Volume 8 "Facilities".

f) Remote PIs Facility

The remote PI facility is where the instrument unique planning and sequencing takes place, the instruments are monitored, and the science data is processed into science data products. Requirements on this facility are found in the Remote Operations Facility Plan [TBD].

g) Planetary Data System (PDS)

The Planetary Data System provides the long term data archiving function for the MGS Mission, as well as other missions in the future. Requirements on this facility are found in the Project Data Management Plan. Submittals of MGS science data to the PDS will be made directly by the science teams.

h) Spacecraft Ground Support Equipment (GSE)

Spacecraft contractor test equipment, located at contractor site (and later at KSC) will be used to support spacecraft system test, sequence validation, and S/C-MOS compatibility testing.

I) Spacecraft Test Laboratory (STL)

Independent test equipment, utilizing non-flight hardware and software, which emulates spacecraft functions. The STL will be used in the pre-launch and post-launch phases for sequence testing, capability development and demonstration, and flight software development and verification. STL may also support anomaly investigations. Requirements on the STL are addressed in TBD. Detailed specifications are contained in spacecraft system contractor CDRL items TBD.

3.2 DATA SYSTEM PHASING

3.2.1 Data System Phases

The MGS GDS will be delivered in three major phases: the Development [D] system, the Launch [L] System and the Encounter [E] System. The Development system will provide an environment for adaptation of the Mars Observer GDS to the needs of the MGS spacecraft and mission and for development of basic flight sequences for spacecraft control. The launch phase will support flight sequence updating and testing, launch operations, spacecraft acquisition and cruise phase activities up to 90 days prior to Mars orbit insertion (MOI). The encounter phase will support the remainder of the mission including MOI, aerobraking, spacecraft checkout, gravity calibration, mapping, data relay, and final production of mission and science data.

The following "capability need dates" apply. These dates correspond to the start of Project GDS testing and subsequent delivery to operational use (and are shown for information only; These dates are controlled by the MGS GDS Schedule (Level 4).

	Test start	D to O
D1.0	8/1/95	9/1/95
L1 .0	11/1/ 95	2/1/96
L1.1	5/15/96	7/1/96
E1.0	1/1/97	4/1/97

3.2.2 Development [D] System Functions

Figure 3.5 MGS GDS Prototype Configuration shows the initial version of the hardware environment for incremental development of GDS software and capabilities. The Development system provides capabilities to develop the GDS, the MOS, and flight sequences. The system will include the following functions:

a) Generation of spacecraft sequences;
b) Generation of spacecraft commands and MOS files and flow between JPL, spacecraft system contractor, and Science sites;
c) Support development of the spacecraft team data system, the S/C and its checkout station, and the STL;
d) Direct telemetry flow from S/C to JPL/AMMOS;
e) Local command and telemetry processing at the spacecraft contractor's site.
f) capture and Reed Solomon decoding of downlink telemetry;
g) decommutation of spacecraft engineering data;
h) storage of telemetry and engineering channel data in the Project Database;
i) display and monitor of the spacecraft engineering data; and
j) extraction of downlink data from the Project Database for subsequent analysis;
k) support for MGS telemetry simulation and simulation from spacecraft telemetry files produced by GSE or STL

3.2.3 Launch [L] System Functions

The Launch system provides all the capabilities necessary for sequence validation, MOS test and training, MOS-spacecraft compatability testing, launch and cruise up to 90 days prior to Mars Orbit Insertion. This includes the capabilities of the D system, and the additional following capabilities:

a) tracking and radio science data acquisition and routing;
b) DSN monitor;
c) command radiation capability;
d) spacecraft engineering functions including prediction, comparison of predictions with downlink actuals, fault isolation support and maneuver implementation capability;
e) a complete project database including all capabilities necessary for managing mission data;
f) navigation capability appropriate for the launch and cruise phases of the mission, including interfaces between the Navigation Computer and MGS/MGDS workstations and project database as well as a direct interface between the Navigation Computer and the DSN; and NAIF tools for generation and utilization of S & P kernels by NAS;

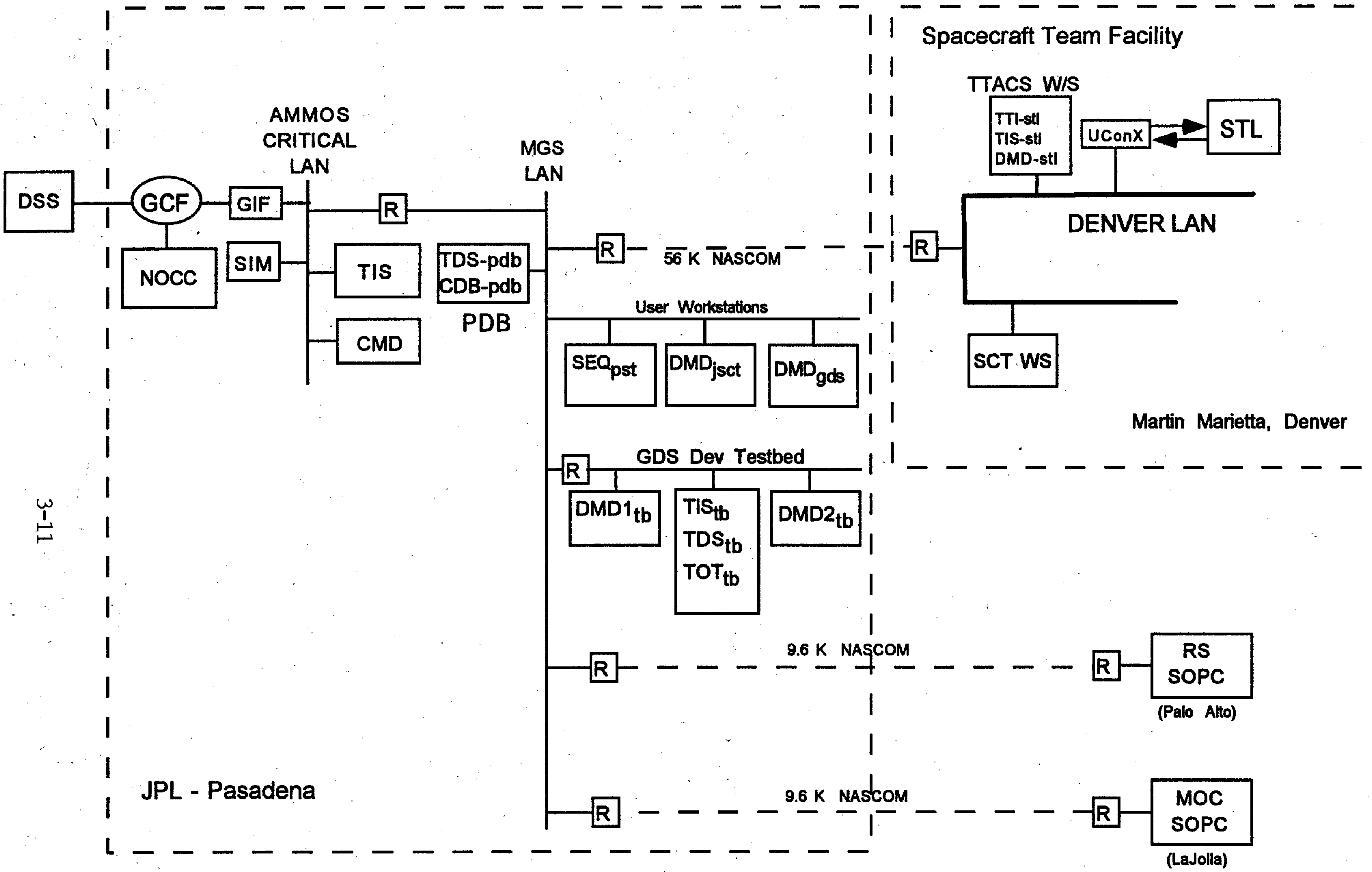


Figure 3.5 Mars Global Surveyor Ground Data System Prototype Configuration

SOURCE: ___ DSS
___ STL (Denver)
___ SIM (JPL)

LEGEND:

DSS - Deep Space Station
GCF - Ground Communications Facility
MOC - MGS Camera
NOCC - Network Operations Control Center

PDB - Project Data Base
RS - Radio Science
STL - Spacecraft Test Laboratory
TTACS - Test Telemetry & Command System

R - ROUTER

(gdsproto.cvs/12-6-94)

g) a distributed command request system supporting the spacecraft team for spacecraft operations during cruise, all SOPCs for instrument operations during cruise, and for the Sequence Team for integration and translation of commands into the Project Database;
h) data lines between JPL and SOPCs, provide 56KB circuits to PI/TL for participation in Launch GDS Test;
i) communications between JPL and MIL-71 during launch, as described above in the configurations section;
j) tracking during DSN acquisition and cruise;
k) Command Tracking capability including electronic database;
l) operations automation capabilities (eg, scripted uplink, automated logging)
m) initial telecom performance prediction software; and
n) the attitude reconstruction function for spacecraft pointing .

3.2.4 Encounter [E] System Functions

The Encounter system provides all the capabilities necessary for Mars Orbit Insertion and the Mapping and Relay phases of the mission. This includes all the capabilities for the Launch system, and the additional following capabilities:

a) SOPCs for Interdisciplinary Science Teams;
b) improved navigation capabilities including the software required for aerobraking and a more accurate accounting of the Mars gravitation field and atmospheric effects on the spacecraft orbit and the major propulsive maneuvers MOI, ABM, TL0;
c) the footprint function to support science planning efforts;
(Note: The MGS GDS retains the Mars Mapper program developed for MO; it is available but is not supported by MOSO or Project resources.)
d) Final Ops hardware capability including 14 gigabytes of online PDB storage and 56KB circuits to IDS SOPC's;
e) Capability to complete development of PI/TL/IDS SOPC software and JPL software development to support MOI and orbital operations; and
f) final telecom performance prediction software.

3.3 REQUIREMENTS ALLOCATION

3.3.1 Requirements Allocation to GDS Phases

In the following sections, data system functional requirements are annotated, in square brackets, to indicate the initial GDS phase to which they apply (e.g. [D], [L], [E], etc.). Except where noted, the final dates for which the capabilities shall be ready for GDS testing are:

D - Development	August 1, 1995
L - Launch 1.0 (MOS Compatability)	November 1, 1995
L - Launch 1.1	May 15, 1996
E - Encounter/Mapping	January 1, 1997

3.3.2 Requirements Allocation to Providers

In the following sections, data system functional requirements are annotated, in parentheses, to indicate the organization required to provide the capability; e.g. (MOSO), (MGS-JPL), (MGS-CTR), (MGS-SCI), (MGS-COMMERC), (DSN)

3.3.3 Requirements Allocation to GDS Subsystems

In the following sections, data system functional requirements are annotated, in braces, as needed, to indicate the MGS GDS subsystem to which they have been allocated . e.g., {DSR}

3.4 DATA SYSTEM FUNCTIONAL REQUIREMENTS

The following paragraphs specify the functional design and allocation of requirements within the MGS Data System. Figure 3.8 provides a functional overview of the MGS Data System. Within the MGS Data System, there are 6 functional subsystems comprising the MGS Ground Data System (GDS), and 5 additional external systems. The 6 GDS Subsystems are:

a) Science Support Subsystem (SSS)

b) Planning and Sequencing Subsystem (PSS)

c) Navigation Analysis Subsystem (NAS)

d) Engineering Analysis Subsystem (EAS)

e) Data Acquisition and Command Subsystem (DAC)

f) Data Storage and Retrieval Subsystem (DSR)

The five external systems are:

a) The Mars Global Surveyor Spacecraft

b) Launch Unique Functions

c) Long Term Archiving Function - Planetary Data System (PDS)

d) Science Planning & Analysis (SPA) - A subset of the Science Investigation Teams

e) Verification and Test System - Spacecraft Test Laboratory (STL)

The subsystems and teams do not always have one to one mapping. The following table shows the subsystems and teams relationships.

Subsystem	*provides functions to*	Teams
PSS	*provides functions to*	Sequence, S/C, Sci Ops
NAS	*provides functions to*	Navigation
EAS	*provides functions to*	S/C
DAC	*provides functions to*	RT Operations
DSR	*provides functions to*	all
SSS	*provides functions to*	Science Ops

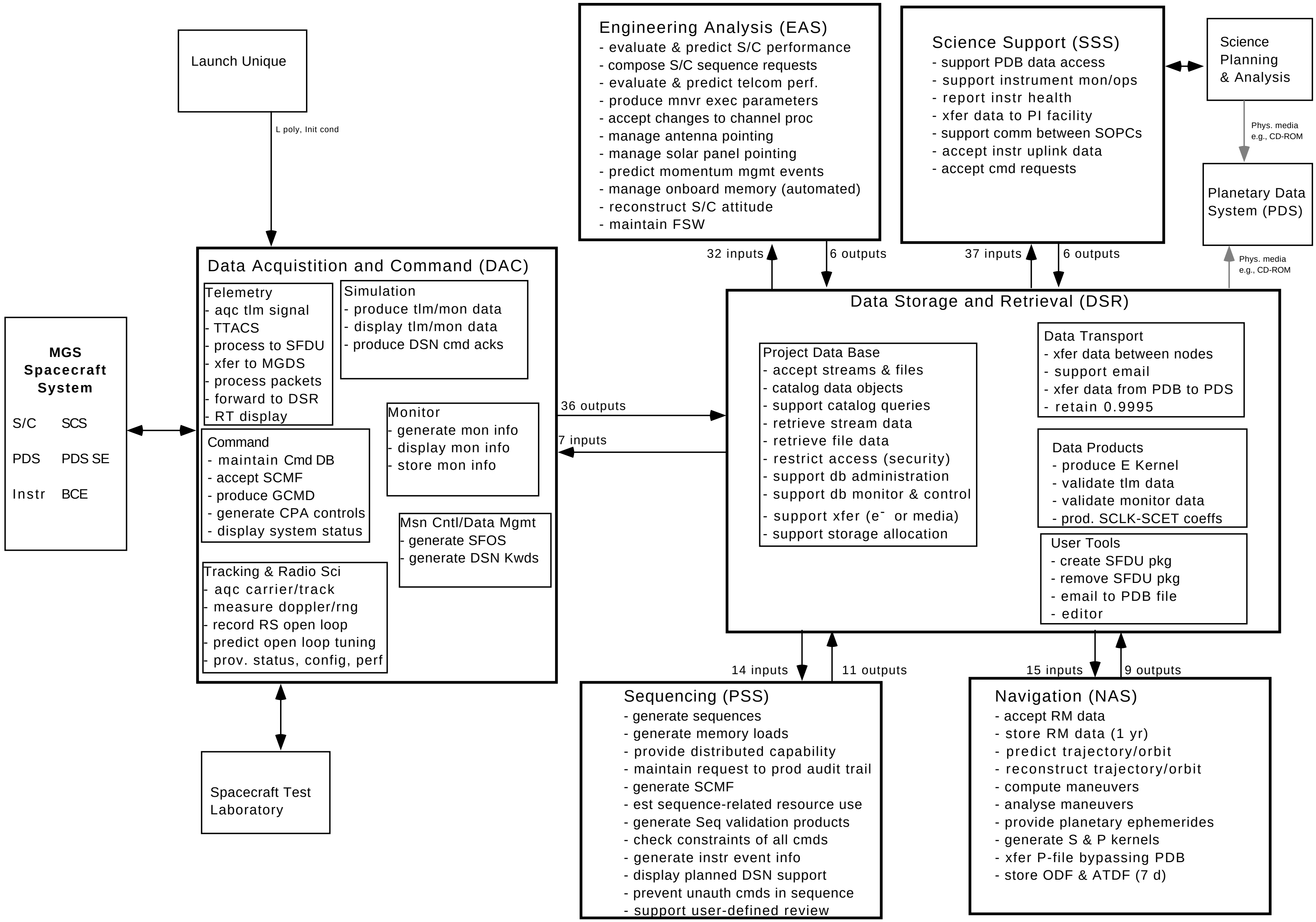


Figure 3.8 Mars Global Surveyor Ground Data System Functional Block Diagram

Due to this characteristic, all requirements of a subsystem levied by teams shall appear in that subsystem; however other subsystems may reference those requirements.

The following paragraphs represent the functional requirements on the external and internal subsystems of the MGS Data System.

3.4.1 Spacecraft Requirements

The Spacecraft system is composed entirely of Project furnished hardware and software. The Spacecraft system includes test equipment and software, as well as flight hardware and software. Interface requirements are levied against the spacecraft system, as specified in Contract Deliverables SE001 "Spacecraft Performance and Interface Specification", SE009 "Block Dictionary", SE012 "Engineering Telemetry, Command Dictionary and Telemetry Calibration Handbook", E013 "Flight Rules and Constraints" and SW-004 "Flight Software Design". Detailed interface specifications and operational interface agreements are contained in MOS Volume 5, "Interfaces".

3.4.2 Launch Unique Requirements

The Launch Unique Subsystem is composed entirely of hardware and software furnished by McDonnell Douglas Aerospace, KSC and MILA. The Subsystem provides for the processing and forwarding of launch polynomial file(s), to JPL, and generation of state vector information. Note that spacecraft telemetry during the launch ascent is <u>not</u> required MGS. The interface requirements for this external system are specified in Contract Deliverable TE001 "Spacecraft Integration Test and Launch Operations". Detailed interface specifications and operational interface agreements are contained in MOS Volume 5, "Data System Interfaces".

3.4.3 Long Term Archiving Requirements

The Long Term Archiving Subsystem is composed entirely of hardware and software furnished by the Planetary Data System. The interface requirements levied against PDS are specified in Appendix A. Detailed interface specifications and operational interface agreements are contained in MOS Volume 5, "Interfaces".

3.4.4 Science Planning & Analysis Requirements

The Science Planning and Analysis Subsystem is composed of investigator-provided software and hardware. The interface requirements levied against this external system are specified in Appendix A. Detailed interface specifications and operational interface agreements are contained in MOS Volume 5, "Data System Interfaces".

3.4.5 Verification & Test Requirements

The Verification and Test Subsystem consists of independent test equipment, utilizing flight-equivalent hardware and software, which emulates spacecraft functions. The STL will be used in pre-Launch sequence testing and capability development. In the post-Launch phase, STL use may expand for sequence testing, and demonstration, flight software development and verification, and anomaly investigations. Functional and performance requirements are [TBD]:

Test uplink sequence and/or command loads via the networked AMMOS,
Provide telemetry flow of test results directly to the networked AMMOS,
Provide automated setup for test cases in the STL.

Detailed requirements are contained in spacecraft system contractor CDRL items ST-001 "STL System Requirements Specification" and ST-002 "STL Design Specification" which includes external data (STL/MOS) interfaces. Interfaces are also enumerated in Appendix A of this document.

3.4.6 Science Support Subsystem (SSS) Requirements

The Science Support Subsystem provides hardware and software to assist the Investigation teams in uplink planning and accessing Mission data (science, engineering, and ancillary), and provides a set of multimission tools to support the Investigation team in monitoring instrument operation. The functional requirements on the Science Support Subsystem are to:

a) Transfer and store project data including catalog information, available SPICE Kernels, Spacecraft Engineering Reports, instrument health reports, and instrument telemetry from the project database to the PI/TL/IDS SOPCs. (MOSO) [L]

b) Provide tools for PI's and TL's to monitor instrument health and operation. (MOSO) [L]

c) Provide mechanism for instrument health report submision to the Project Data Base for use by the Spacecraft Team. (PI/TL) [L]

d) Provide an interface for transfer of data files between the SOPC and the PI/TL/IDS host facility. (MOSO) [L]

e) Provide electronic communication services between SOPCs, including electronic mail and binary file transfers. (DSN, MOSO) [L]
(DSN - physical comm services; MOSO - protocol support.)

f) Accept program and table upload files for the instruments. (MOSO) [L]

g) Accept command request files for instrument commanding. (MOSO) [L]

3.4.7 Planning and Sequencing Subsystem (PSS) Requirements

The Planning and Sequencing Subsystem is composed of both project and MOSO furnished hardware and software. The functional requirements on the Planning and Sequencing Subsystem are to provide capabilities to:

a) Generate sequence inputs for prelaunch Flight Sequence Verification (in spacecraft system test configuration and/or in the STL). (MGS, MOSO) [D]

b) Generate approved, validated flight sequences through controlled adaptation of pre-defined Mission Sequence Plan (MSP) sequences and blocks to accomplish desired spacecraft, ground, and payload activities. (MOSO, MGS) [D]

c) Mars Mapper (developed to support geometric view planning for Mars Observer) remains available to Project users but is not a committed or supported capability.

d) Generate the required Spacecraft sequencing memory contents. (MOSO, MGS) [E]

e) Provide a distributed sequencing capability, with standalone sequencing software at the SOPCs and project workstations, and with coordination of the sequencing activities via the Project Data Base (MOSO, MGS) [L].

f) Generate and retain an automated, electronic audit trail of the transitions from user command requests to resulting sequence products. (MOSO, MGS) [L]

g) Generate the Spacecraft Message File (SCMF) containing the uplink command bits for transmission to the MGS Spacecraft. (MOSO, MGS) [D]

h) Generate estimates of spacecraft consumables and resources required for sequences, compute resulting margins, and detect any guidelines violated. (MOSO, MGS) [D]

i) Generate products to validate uplink command sequences and to monitor S/C and ground system sequencing performance.(MOSO, MGS) [D]

j) Provide constraint checking of all non-stored interactive commands and validation of non-stored non-interactive science and engineering commands. (MOSO, MGS) [D]

k) Generate Science-relevant S/C and instrument event information for inclusion in the E kernel, for use by the Science Support Subsystem. (MOSO, MGS) [L]

l) Generate displays of preliminary and final negotiated DSN coverage periods, for use by the Project operational teams. (MOSO) [D]

m) Preclude the inclusion of unauthorized commands in flight sequences, including validation of requestor-command destination relationship and protection of flight-sequence files from unauthorized changes prior to release. (MOSO) [D]

n) Sequence producing software shall be executable via command line interface. (MOSO) [D]

o) Sequence products shall be reviewable via electronic tools which accept user-defined review criteria and output exceptions to those criteria. (MOSO) [D]

p) Support express commanding, i.e., the ability to send an authorized, interactive command to the S/C within 30 minutes of invoking the capability and without assembling a nominal Sequence Team. (MGS) [L]

3.4.8 Navigation Analysis Subsystem (NAS) Requirements

The Navigation Analysis Subsystem consists of Project and MOSO provided hardware and software resources. The functional requirements on the NAS are to:

a) Accept properly formatted and pre-conditioned radiometric data along with calibrations and corrections. (DSN) [L]

b) Provide a 12 month storage capability for all radiometric data acquired during the MGS Mission. (MOSO) [L]

c) Generate trajectory, and orbital data to predict and reconstruct the trajectory of the spacecraft throughout the mission. (MOSO, Project) [L]

d) Perform maneuver computations and analysis for the Downlink Operations Team to determine requirements and specifications for Trajectory Correction Maneuvers (TCMs), the Mars Orbit Insertion Maneuver (MOI), Aerobraking Maneuvers, and Orbit Trim Maneuvers (OTMs) during both the insertion and mapping phases. Provide reconstructed trajectory for all propulsive maneuvers. (Project) [L]

e) Provide accurate planetary and natural satellite ephemerides and planetary partial derivatives. (MOSO) [L]

f) Generate and store S & P Kernels in the PDB. (MOSO, MGS) [L]

g) Provide workstations for orbit determination and maneuver related calculations, S and P Kernel generation, and interfacing and transference of files between the workstations, the Navigation computer, and the Project Database. (MOSO, MGS) [L]

h) Provide navigation products for use during flight sequence development and flight sequence verification. (MGS) [D]

i) Provide a direct transfer of the P-file between NAS and the DSN; this procedure shall by-pass the PDB. (MOSO, DSN) [L]

j) Provide a 7 day storage capability of the ODF and ATDF files (after the files are delivered to the NAS) with immediate recall (<=15 minutes) during working hours (Monday through Friday). For recall after this 7 day period, file delivery shall occur within 8 working hours. (DSN) [L]

k) Provide appropriate modelling of the Mars atmosphere and gravity field for support of aerobraking and orbital operations, (MGS) [E]

3.4.9 Engineering Analysis Subsystem (EAS) Requirements

The Engineering Analysis Subsystem is composed of MOSO and Project furnished hardware and software. The functional requirements on the Engineering Analysis Subsystem are to provide capabilities to support the following:

a) Non-real time analysis, assessment, and prediction of spacecraft engineering performance using spacecraft engineering telemetry and ground-based measurements. (MOSO, MGS) [L]

b) Preparation of engineering sequence requests. (MOSO) [L]

c) Analysis and long term prediction of uplink and downlink telecom link performance (including command, telemetry, and radio metric links using spacecraft engineering telemetry, monitor, and trajectory data). (DSN, MGS, MOSO) [L] (MOSO provides software, not operational, support.)

d) Processing of maneuver design requirements and provide spacecraft execution parameters. (MGS) [L]

e) Accept changes to engineering telemetry decommutation maps, alarm limits, suppression tolerances, and DN to EU conversion data. This includes automated, streamlined input of standard processing parameters. (MOSO, MGS) [L]

f) Analysis of spacecraft antenna attitude (pointing) and generation of antenna pointing command parameters. (MGS) [E]

g) Analysis of solar panel attitude (pointing) accuracy and generation of on-board solar panel pointing parameters. (MGS) [E]

h) Prediction of the time, direction, and magnitude of spacecraft momentum management events, and to evaluate and reconstruct those events. (MGS) [L]

i) Prediction of spacecraft subsystem memory contents. (MGS) [L]

j) Comparison of spacecraft subsystem memory readout telemetry with predicted contents. (MOSO) [L]

k) Preparation of engineering summary reports. (MGS) [L]

l) Generation of *a posteriori* spacecraft attitude and antenna pointing information from engineering telemetry in C kernel format, to be provided to the Science Support, and Long Term Archiving Subsystems. (MGS) [E]

m) Preparation of engineering parameters and files needed for FS Verification testing. (MGS) [D]

n) Automated flight software tracking, analysis, and management (as in i. and j. above). (MGS-MMTI) [L]

o) Realtime viewing of STL-generated telemetry. (MOSO) [D]

p) Flight Software maintenance capability (including Payload Data System). (MGS-MMTI) [L]

3.4.10 Data Acquisition and Command Subsystem (DAC) Rqmts

The Data Acquisition and Command Subsystem is composed of six major functional areas:

A. Telemetry
B. Command
C. Monitor
D. Simulation
E. Tracking & Radio Science
F. Mission Control and Data Management

The functional requirements are to provide capabilities to:

a) Display telemetry data as required by the Mission Operations teams. (MOSO) [D]

b) Local, dedicated telemetry display from the S/C and command entry to the S/C via ground support equipment during S/C integration and test and launch operations. (MOSO) [D]

c) Display monitor data as required by the Mission Operations teams. (MOSO/DSN) [L]

d) Command the spacecraft including control and status displays (MOSO/DSN) [L]

e) Display status and configuration of various MGDS component subsystems (MOSO) [L]

f) Display DSN performance and configuration, including DSN telecom and radio science data (DSN) [L]

g) Measure downlink carrier Doppler and range. (DSN, MOSO) [L]

h) Record and deliver in realtime, open-loop radio science downlink carrier data. (DSN,MOSO) [L]

i) Acquire and frame synchronize telemetry data from the MGS Spacecraft, both via RF link and hardline via GSE. (MOSO,DSN) [D]

j) Decode convolutional (DSN) and Reed-Solomon (MOSO) encoded data. [D]

k) Time-tag (with earth receive time, spacecraft clock, and spacecraft event time), extract, decommutate, and channelize engineering telemetry. (DSN, MOSO) [D]

l) Time-tag (with earth receive time, spacecraft clock, and spacecraft event time) science telemetry. (DSN, MOSO) [D]

m) Generate simulated data types (telemetry, monitor, radio science, and radio tracking) from internal stored tables, and tapes of actual S/C telemetry. (DSN)[D], (MOSO)[D]

n) Provide simulation of a DSN Command Station (MOSO) [L]

o) Acquire radiometric tracking data. (MOSO/DSN) [L]

p) Provide updated command standards and limits tables including changes and command subcarrier frequencies. (MOSO) [L]

q) Support the command process with capabilities for electronic command request/origination and recordkeeping of the progress and disposition of each command request through the uplink process for both stored (sequenced) and non-sequenced commands. (MOSO) [D]

r) Support an automated capability to notify key personnel of significant spacecraft anomalies during non-standard hours. (MGS) [L]

s) Support a capability to display standard spacecraft and mission data for key personnel at locations other than their normal Project workstation and network location, e.g., for spacecraft anomaly resolution after normal work hours or on travel. (MGS) [L]

t) Support express commanding, i.e., the ability to send an authorized, interactive command to the S/C within 30 minutes of invoking the capability and without assembling a nominal Sequence Team. (MGS) [L]

u) Support automated logging of significant events by operational personnel. (MOSO) [D]

v) Support sequence of events review and approval processes. (i.e., via Sequence of Events Generation capabilities.) (MOSO) [D]

3.4.11 Data Storage and Retrieval Subsystem (DSR) Requirements

The Data Storage and Retrieval (DSR) Subsystem is composed of MOSO furnished hardware and software. The DSR Subsystem includes general purpose MGDS/AMMOS database capabilities, the specific Project Data Base (PDB) architecture retained from the Mars Observer GDS, and certain portions of the PDB content. Much of the actual data which will reside in the MGS PDB will be produced by other subsystems. The functional requirements on the Data Storage and Retrieval Subsystem are to:

a) Accept data products from all other GDS subsystems. (MOSO) [L]

b) Store and catalog downlink data and data products in the Project Data Base (PDB) for subsequent access by other subsystems. The catalog capability is to include access of data by data type, instrument, SCET, ERT, SCLK and other project-designated attributes. (MOSO) [L]

c) Provide access to downlink data and data products by other GDS subsystems and teams [L]. (MOSO)

d) Provide a capability to generate E Kernels. (MGS) [E]

e) Provide an interface to the Planetary Data System for long term data archiving of science packets and related ancillary data. Note that archiving of final/reduced science products is a responsibility of the individual science teams. (MOSO) [E]

f) Provide tools for interfacing with the project database including: Catalog search, file submittal & retrieval, PDB data object preparation, PDB data object header analysis and data access, retrieval of telemetry, monitor, radio science, QQC, and channelized engineering data. (MOSO) [L]

g) Provide electronic mail capability. (MOSO) [D]

h) Capabilities for PDB data backup & recovery. (MOSO) [L]

i) Capabilities for PDB data security and access control. (MOSO) [L]

j) Provide a development era PDB capability including access to uplink files by PSS software [D], and access to engineering and science telemetry [D]. (MGS-JPL)

k) Provide tools for interfacing with DSN-NOCC and NAV-HP750 nodes. (MOSO) [L]

3.4.12 Security Requirements {All subsystems} (MOSO,MGS,DSN,PI/TL)

This section contains the system level security requirements for the MGS/GDS operational systems, including the Development, Launch and Encounter systems. Security requirements apply to all GDS subsystems and organizations providing GDS capabilities. Detailed security requirements are provided in the MGS Project Security Plan (542-404) in response to the system level requirements.

a) Provide security capabilities for all computers directly or indirectly connected to the MGS Local Area Network (LAN) to enable:

1) Mandatory user identification and authentication of each person at all such computers.

All identification shall be to a specific individual. [L]

2) Software which ensures that all passwords are secure for the entire lifetime of the user-id, and that no passwords are more than three months old. [L]

3) Provide an audit of all persons accessing the computer. [L]

4) Provide virus control which minimizes the risk of contamination of mission assets. [L]

5) Provide program and data access control for sensitive mission programs and data, including command software and data and mission operations software and data. [L]

b) The facilities containing any MGS workstation or computer shall be physically secure.

Physical security shall employ a physical or electronic lock and key allocated to each authorized person using the facility. [L]

3.4.13 Configuration Management Requirements (MOSO,DSN,MGS,PI/TL)

The following requirements are applicable to the configuration management function. Requirements apply to all organizations supplying GDS capabilities.

a) The CM Function shall provide for Configuration Management of hardware, software, documentation, operational procedures and data. [D]

b) The CM function shall provide a capability to maintain successive versions of operational data and procedures. [L]

c) The CM function shall provide a capability to maintain the configuration of current equipment and network. [D]

d) The CM function shall provide the capability to maintain the configuration of current operational software. [D]

e) The CM function shall provide a capability to track failures and change requests from inception to dispensation. [D]

Automated, electronic problem reporting and resolution database shall be used to manage MGS anomalies in a paperless mode.

f) The CM function shall provide a report of the current status of configuration items, and a history of changes to configuration items. [D]

Automated, electronic change request and progress database shall be used to manage MGS Data System evolution in a paperless mode.

3.4.14 GDS-Level Requirements

This section contains GDS functional requirements which apply to all GDS subsystems or which do not apply to any specific subsystem.

a) Provide the capability to quickly reconfigure a GDS workstation (in terms of MOSO-provided software set) to enable a different set of functional capabilities. (Assuming hardware compatibility.) For example, the ability to quickly reconfigure a sequence workstation to perform spacecraft analysis functions. (MOSO) [L]

b) For each major software delivery, provide a complete set of user documentation. (MOSO) [D]

c) Resource Allocation Formatting Tools
Users of the Deep Space Network require a comprehensive set of tools to interface with the TMOD scheduling systems. These tools shall record, print, compare, graphically display and compute user needs, requests, and allocations for DSN support.

3.5 DATA SYSTEM INTERFACES

The interfaces for the ground data system and the external subsystems are provided in Appendices A. Interface details, in the form of Software Interface Specifications (SIS's) and Operational Interface Agreements (OIA's) are contained in MOS Specification Volume 5, "Interfaces", (MO 542-409, Vol 5).

3.6 DATA SYSTEM PERFORMANCE REQUIREMENTS

Performance requirements have been placed on the MGS Data System in order to meet mission and science requirements. These requirements are provided below. As used in this section the terms "maximum" and "nominally" refer to response times 99% and 75% of the time, respectively.

a) The GDS shall acquire and deliver no less than 94% (by category) of the telemetry, radio science occultation and tracking data. That error budget is further apportioned: the DSN shall deliver no less than 95% of the data properly input to the DSN; MOSO shall deliver no less than 99% of the data properly input to MOSO. {DAC,DSR} (MOSO, DSN, MGS) [L]

b) Capability to support sequence planning and uplink generation for a 28 day sequence in less than 28 calendar days. {PSS,DAC} (MOSO, MGS) [L]

c) Stored sequence update capability shall be provided to support:

1) Updates of spacecraft ephemerides every 30 days for launch. {NAS, PSS, EAS} (MGS) [L]

2) Updates of spacecraft ephemerides every 7 days for encounter. {NAS, PSS, EAS} (MGS) [E]

3) Update of equator crossing times twice per week. {NAS,PSS} (MGS) [E]

4) Update of the skeleton stored sequence during the first 10 days of the planning cycle. {PSS, EAS, SSS} (MOSO, MGS) [L]

d) Overall induced error rate in the Data System shall be less than 1 error induced in 10^7 bits transferred. Induced error rate shall be measured at the input to the DSN, and at the delivery to the Principal Investigators data analysis facility or Engineering workstation. {DAC, DSR} (DSN, MOSO) [L]

When science and engineering (S&E) telemetry is received by the DSN, with a bit SNR (E_b/N_o) at input to symbol-synchronization of at least 4 dB, TMOD shall provide quality, continuity and latency for science packets delivered to the project database, such that, within 12 hours of data receipt, the delivered data contains, on average, no more than one packet gap or error, within 10,000 packets. The S&E telemetry stream is both Reed-Soloman and Convolutionally encoded. A MOC packet is about 10,000 bits in length. (DSN, MOSO) [L]

e) Performances of data delivery in the Data System depend on types of data, and shall be measured and specified in four areas:

1) Science and Mission Analysis Data Delivery.

Telemetry, monitor, and Radio Science data shall be made available for access in the Project Data Base, measured from the input to the DSN Antenna, within 24 hours maximum, and 30 minutes nominally. {DAC, DSR} (DSN, MOSO) [L]

2) Radiometric Data Delivery Schedule

(A) During interplanetary cruise, edited ODF/ASTD files shall be provided to the Downlink Operations Team twice per week.

During period of intense navigation activity, such as injection, TCMs, and the MOI maneuver, ODF/ASTD files are required within one hour of the end of the tracking pass. Partial data files may be required immediately after injection and the MOI maneuver.

(B) During the orbit insertion phase (MOI maneuver to beginning of mapping) deliveries of the ODF varies from one per day to three or four per day as specified in the Data Delivery and Conditioning section of the DMR.

(C) During the mapping phase, edited ODF files are required 12 hours after the end of a tracking pass (excluding weekends). If this time should occur outside of normal working hours 8:00 a.m. to 5:00 p.m. local time (Monday through Friday) then that data shall be available to the Navigation Team by 8:00 a.m. of the next working day.

For all propulsive maneuvers during the orbit insertion phase data will generally be required within one hour of the end of the tracking pass.

During mapping tracking data are required within 1 hour of the end of a pass whenever a propulsive maneuver occurs with that pass. This is subject to the normal working hour guidelines given above.

{DAC,DSR} (DSN, MOSO) [L]

3) Engineering Telemetry Data Delivery

Engineering Telemetry shall be made available for access in the Project Data Base, measured from the input to the DSN Antenna to the Multimission or Engineering Analysis workstations in 2 hours maximum, and 5 minutes nominally. {DAC, DSR} (DSN)[L] (MOSO)[D]

4) SPICE Data Delivery.

(A) Fully processed SPICE kernels shall be available to the PI's and Engineering Analysts within 7 working days, measured from the input to the DSN Antenna to the PI/TL/IDS's or Engineer's analysis equipment. {NAS, EAS, DAC, SSS, DSR} (MOSO, MGS) [L,E]

(B) C kernels shall be available to the PI's and engineering analysts within 14 working days of receipt of relevant spacecraft telemetry. {EAS, SSS, DSR} (MOSO,MGS) [E]

f) The Ground Data System shall be able to accept, verify, process, and uplink 4000 non-interactive, non-stored, Science words per work day (a word is 16 bits). This is in addition to the stored sequence command capability. {PSS, DAC} (MOSO, MGS, DSN) [L]

g) The Ground Data System shall process and uplink non-interactive Science non-stored command requests within six hours, subject to project staffing and DSN tracking schedule. {PSS, DAC} (MOSO, MGS, DSN) [L]

h) The GDS shall provide capabilities to process and uplink an interactive command request within 18 hours, during non-critical periods {PSS,EAS,DAC} (MOSO,DSN) [L]

i) The Ground Data System shall accept, verify, process, and uplink up to 25 interactive commands per work day. {PSS, DAC} (MOSO,DSN,MGS) [L]

j) In an emergency, the capability shall be provided to produce input to the command system (SCMF on PDB), of up to 10 spacecraft commands within 15 minutes. This 15 minutes shall be measured from the completion of S/C command data entry into the SEQGEN until the SCMF is resident on the PDB. (excluding human intervention time). (MOSO) [L]

k) Provide the capability to begin transmission to DSN for approved command files within 2 hours nominally, and within 10 minutes in emergency situations, of SCMF being placed on the PDB. (excluding human intervention time) {DAC} (MOSO) [L]

l) Begin radiation to S/C for emergency command files, within 5 minutes of command file receipt (assumes DSN uplink capability is configured).

m) The Ground Data System shall be capable in special circumstances of sending authorized, interactive commands, known as "Express Commands", within 30 minutes of invoking the Express Command option and without assembling a nominal Sequence Team staffing. {PSS,DAC} (MOSO,DSN,MGS} [L]

n) The Ground Data System shall generate a S/C ephemeris at the beginning of a Sequence Generation cycle that is valid for the duration of the generated sequence, i.e. valid for the entire Sequencing cycle, during mapping operations after gravity orbit calibration. {NAS} (DSN, MGS) [E]

o) The Ground Data System shall begin transmitting requested data to a PI/TL/IDS or Engineering Analyst within 2 minutes maximum, and 5 seconds nominally, of Data or Catalog Request time for data stored on-line, and 30 minutes maximum, and 10 minutes nominally, for data stored off-line measured from the time the request is entered in the PI/TL/IDS or Engineering Analyst's workstation to the time the requested data start to flow to the requestor's workstation. {DSR} (MOSO) [E]

p) Begin transfer of data between the PDB and DSN or Navigation Computer nodes within 2 minutes of initiation of a transfer request at an MGS workstation, Navigation Computer or DSN node. {DSR} (MOSO) [L]

q) The ground data system shall be capable of storing on-line, in user-accessible form, all planning data types for 12 weeks, all raw spacecraft engineering, radio tracking and monitor data for 3 weeks, all raw science data for 3 weeks, and all processed science, engineering & radio tracking data for 4 weeks. In addition, these data shall be stored off-line for the duration of the project. {DSR} (MOSO) [L]

r) The ground data system shall archive PDB data until the end of the project. {DSR} (MOSO) [L]

s) The ground data system shall provide knowledge of spacecraft position within 7 working days of receipt of tracking data at the NAV Computer. {NAS} (DSN, MOSO, MGS) [L]

t) The project database shall be accessible on-line 24 hours a day. {DSR} (MOSO) [D]

u) Data submitted for storage to the Project Data Base shall be backed-up within 24 hours, maximum, from receipt at the Project Data Base. {DSR} (MOSO) [L]

v) Provide for recovery of time-critical PDB files within 5 minutes (plus operations time) in the event of loss or damage. (MOSO) [L]

w) MOSO multimission system functions shall have: (MOSO) [L]

MTBF >= 200 hours.
MTTR <= 12 hours.

x) MO workstations and Navigation Computer shall have: (MOSO) [L]

MTBF >= 1 month.

MTTR <= 2 hours (restore capability on another GDS workstation).

MTTR <= 24 hours (restore capability on failed workstation or its replacement)

y) NASCOM data circuits shall have: (DSN) [L]

MTBF >= 500 hours

MTTR <= 12 hours

MTTR <= 1 hour (for Denver/KSC circuits for pre-noticed critical events)

z) The PDB shall handle 45 concurrent file transfers and 45 concurrent stream data queries. (MOSO) [L]

aa) The aggregate transfer rate for PDB file transfers shall be greater than or equal to 8.5 megabytes/minute. (MOSO) [L]

ab) The aggregate packet query processing rate shall be greater than or equal to 765 kilopackets per hour. (MOSO) [L]

ac) The aggregate channel query processing rate shall be greater than or equal to 933 kilopackets per hour. (MOSO) [L]

3.7 OPERATIONAL AND ORGANIZATIONAL CONCEPTS

Volume 3 of the Mission Operations Specification contains descriptions and requirements for Mission Operations organization and operations.

3.8 DATA SYSTEM TEST REQUIREMENTS

Volume 6 of the Mission Operations Specification contains the test requirements and plans relevant to system level testing of the MGS ground data system. Three categories of GDS testing are covered; 1) the ground hardware and software system, 2) verification of flight sequences for eventual use during mission operations, and 3) verification of the compatability of the flight and ground systems. The data system test program has the following guiding principles:

1 Extend the use of the existing Mars Observer ground data system to minimize cost while providing adequate performance and operability to MGS users.

2. Modify or enhance the Mars Obeserver GDS only as necessary for compatability with the MGS spacecraft or to accomodate the MGS Mission System reengineering changes necessary to meet Project cost constraints. A change solely for compatability with the evolution of multi-mission capabilities will be supported by MGS GDS development, testing, and operations if it represents the lowest overall cost.

3. Rely on the suppliers of multi-mission capabilities to adequately integrate and test their MGS support products. Volume 6 will not place specific requirements on the institutional tests that precede the Project GDS tests.

4. To the extent practical, combine the objectives and activities of the GDS testing program with those of the Mission Operations System personnel training program.

3.9 DATA SYSTEM CONFIGURATION REQUIREMENTS

This section contains the requirements for MGS workstations and circuits, including workstation quantities, phasing and configuration, and connectivity requirements.

Individual workstations are required to:

a) Host and execute all MOSO-supplied software needed to provide the required functional capabilities for the referenced subsystem.

b) Meet the performance requirements specified for the referenced subsystem's MOSO-supplied functions.

c) Provide additional storage capacity of 400 MB for MGS software and user files.

d) Provide a mechanism for creating a local backup of the local disk.

e) Meet the minimum configuration defined below, for the referenced type.

Workstations

Category	Type	Description	CPU (MIPS)	Memory (MBytes)	Disk (MBytes)
Sun	SP2	Sun Sparc 2	28	24-64	400-4000
	IPX	Sun IPX	24	24-64	400-4000
	IPC	Sun Sparc 1	16	24-64	400-4000
PC	I3	"IBM" 386	80386		
	I4	"IBM" 486	80486		
	M3	Mac 2ci	68030	8-20	80-200
	M4	Mac Quadra	68040	8-20	80-200
	PPC	Power PC			

Peripherals

CDR	CD_ROM Reader
WORM	Write once, read many
Exe	Exebyte Tape unit
T 1/4	Quarter inch tape unit
Ptr	Laser printer
Eth	Ethernet interface

For Project operations workstations, all must provide access to a laser printer. However, only one laser printer is required for every three workstations. Table 3.1 provides hardware requirements at subsystem level. Table 3.2 provides the detail information of circuits requirements.

Table 3.1 MGS Mission Operations Hardware Summary

Team	Sub	Use	#-Cat/Type	Mem	Disk	Periph
Seq	PSS	Stored Sequence	2-SP2			
		Team Lead (NIPC)	1-SP2			
		S/C Int C	2-SP2			
RT Ops	DAC	Cmd Rad	Multi Msn			
		GS Mon & Config	Multi Msn			
	DSR	Data Mgmt / Archive	1-SP2			
		PDB - TDS	2- SPARC 20			
		- CDB	2- SPARC 10			
		Database Admin	Multi Msn			
Nav	NAS	Analysts	4-SP2			
		Analysts	3-IPC			
		MM Nav	2-HP720			
		NTRAN	Multi Msn			
		DSN NAV	Multi Msn			
S/C	EAS	System Analysis (at JPL)	1-SP2, 1-IPC			
	at Denver:	Sys Admin	2-SP2			
		S/S Analysis	16-SP2			
		FSW	2-µVax			
		STL TTACS	1-SP2			
		SCC TTACS (mobile to KSC)	2-SP2			
		Test Dir (mobile to KSC)	1-SP2			
		BCE support (to KSC)	1- SP2			
MOA	DSR	GDS Maint	4-SP2			
		CM	1-SP2			
Msn Pln	DSR	Ops Support / Sched	1-SP2			
Sci Ops	SSS	Sci Development	1-SP2			
		SIT Lead	1-SP2			
		ERs	1-SP2, 2- IPC			
		NSI server	1-IPX			
		Guest SOPC	1-SP2			
		PI SOPCs	5-SP2			
		IDS SOPCs	6-SP2			

Table 3.2 GDS Circuits Requirements

Types of Circuits	Need Dates	End Dates	Locations
1 56 Kbps	10/1/94	4/1/95	MMTI Denver
1 448 Kbps	4/1/95	1/1/03	MMTI Denver
1 224 kbps	6/1/96	12/1/96	KSC
3 56 Kbps	7/1/95	End of Mission	Mag, MOLA, RS
2 224 Kbps	7/1/95	End of Mission	MOC, TES Locations
6 56 Kbps	2/1/97	End of Mission	IDS Locations

4.0 DATA SYSTEM SUBSYSTEMS

The following sections provide the detailed requirements allocation and design for each of the MGS GDS subsystems. The structure of this document largely retains the form of the Mars Observer specification. The system engineers and authors for the MGS subsystem sections are:

Science Support	Richard Springer
Planning and Sequencing	Steve Wissler
Navigation	Pat Esposito
Spacecraft Analysis	Allen Bucher
Data Acquisition & Cmd	Rich Benson
Data Storage & Retrieval	Rich Benson

4.1 SCIENCE SUPPORT SUBSYSTEMS

This section provides the functional requirements for and the design of the Science Support Subsystem (SSS) of the Mars Global Surveyor (MGS) Ground Data System. The SSS provides those functions that support the mission operations of the science instruments for a remotely distributed Ground Data System. All of the Science Support Subsystem will be provided by the MOSO MGDS, the DSN, and the MGS Science Office.

4.1.1 Introduction

The Science Support Subsystem of the Mars Global Surveyor Data System enables science instrument monitoring and performance evaluation, provides information for producing SPICE I&E kernels, transfer or generation of instrument command parameters to the PSS, and transfers data between the DSR and the SSS. The DSN provides the data links to the remotely located PI/TL/IDS.

4.1.2 Data Transfer Functions

The data transfer functions of the SSS are as follows:

a) Provide tools for the generation of displays of science instrument housekeeping telemetry for the Science Office. MGDS will generate tools to help build displays. MGDS will provide User Guides for Standalone Decom/DMD, while the PIs/TLs provide the inputs.

b) Provide tools to generate displays of S/C engineering telemetry.

c) Provide tools to generate alarm reporting of science instrument telemetry.

d) Provide tools for updating databases of science instrument standards and limits files (containing alarm limits, DN/EU conversion parameters, channel locations, channel names and page displays).

e) Transport science instrument telemetry, spacecraft engineering telemetry, SPICE kernels, DSN Monitor Blocks, Radio Science data, SIM Science packet data, QQC Data and ancillary data from the DAC/DSR to the Science Office.

f) Transport Special Data Products, SPICE kernels and ancillary data from the DSR to the SOPCs for Science Office use. EDRs, Standard and Special Data Products are defined in the Mars Global Surveyor Science Data Management Plan (642-445).

g) Transport E Kernel inputs to the DSR for access by SSS (Science Office) and the Long Term Archiving Subsystem/PDS.

h) Provide tools for updating local SOPC databases for transmitted and received data to/from the PDB. This includes transfer of all ancillary data required for verification of uplink commands, downlink health monitoring, EDRs, DSN monitor blocks, and any other pertinent information. This capability is anticipated to be provided by a commercial database management system residing on the SOPC.

i) Provide tools to perform "Quick Look" health monitoring and display for each investigation team.

j) Provide tools to generate Instrument Health reports to the EAS.

k) Provide I Kernel inputs.

4.1.3 Functional Design

The functional design responsive to sections 4.1.2 and 4.1.3 is shown in Figure 4.1.1. A SOPC (Science Operations and Planning Computer) will be provided for each Experiment (11 total). The SSS functions are:

a) Communications.

Provide a "common look and feel" interface for data transfer between a SOPC and the DSR.

b) Decommutation.

Provide channelization of input packet telemetry from definitions specified in the decommutation map.

c) Data Monitor and Display.

Monitor instrument health and indicate alarms to the analyst for out-of-tolerance conditions from pre-set standards and limits.

d) NAIF Interface.

1) Provide access to the SPICE Kernels in the PDB.
2) Provide a software toolkit to read/utilize the SPICE Kernels.

e) Instrument Commanding.

1) Provide the capability to host PI software for instrument commands (possibly a subset of the instrument Bench Checkout Equipment - BCE software), parameter table loads, and memory loads to be generated on the SOPC.

Instrument commanding software will require approximately 100 MB of SOPC disk storage capacity.

2) Provide an interface to accept such files (see e.1), and a capability to verify the SFDU command format and transfer the files to the Project Data Base.

3) Provide an interface to accept instrument power profiles (text or binary data), verify the SFDU format and transfer the files to the Project Data Base.

f) Hardware and Operating System.

A Science Operations and Planning Computer (SOPC) will be provided to each PI, TL, and IDS. The SOPC will accept raw science telemetry and ancillary data and spacecraft engineering telemetry data. It will provide a quicklook instrument health assessment and accept finished science data and instrument command request files in a Standard Format Data Unit (SFDU) format for transmission to the Project Data Base. In addition to this unit, an Investigator provided computing resource may connect, through a Ethernet interface, with the SOPC workstation. The 6 IDSs may not require all of the above identified capabilities. Figure 4.1.2 shows the data flows and interfaces within the Science Support Subsystem.

The Mars Global Surveyor Radio Science Support Team (RSST) will provide a multimission workstation that shall have connectivity to the PDB. The software that is to be supplied with the SOPCs shall also be provided to this workstation. The capabilities of the RSST workstation shall be the same as those of the Radio Science Team SOPC.

4.1.4 Planning Functional Requirements

There are no SSS unique software planning functional requirements. All planning functions required by the Science Investigations are levied against the Planning and Sequencing Subsystem (Section 4.2). Uplink planning software functional requirements are implemented under the Planning & Sequencing Subsystem, Section 4.2. Hardware functional requirements for the Science Operations and Planning Computer (SOPC) are listed in Section 3.9. The SOPC shall be capable of running a subset of Planning & Sequencing software.

The science and mission planning activities for Mars Global Surveyor do not include requirements for the Mars Observer-developed Mars Mapper program. Use of Mars Mapper by MGS personnel is not precluded or forbidden in any sense, but note that such use is not supported by the MGS Mission System and neither the GDS nor the MOS has resources to maintain or enhance that software.

4.1.5 SSS Functional Requirements

The following paragraphs outline the requirements on the subfunctions of the Science Support Subsystem.

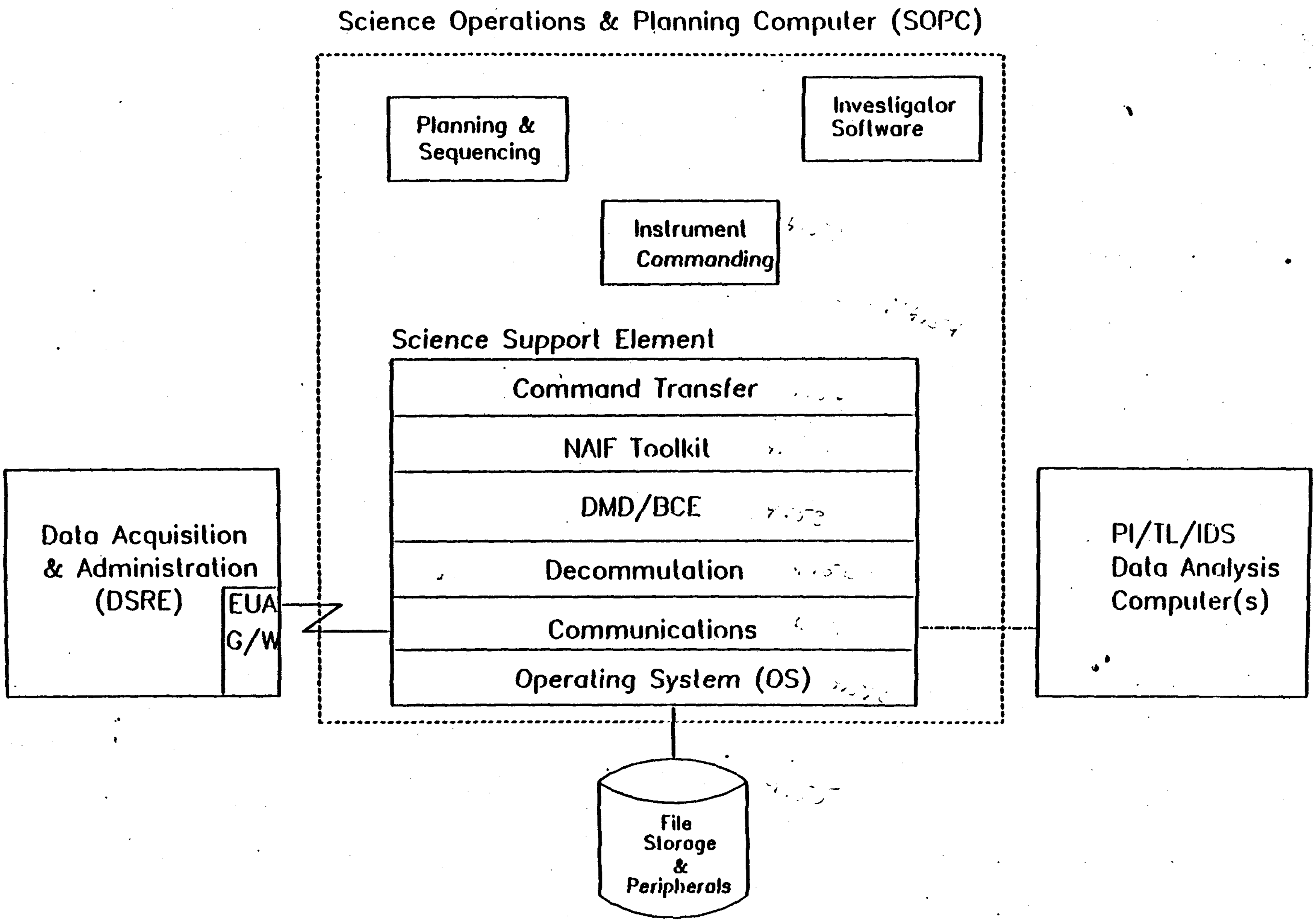


Figure 4.1.1 Science Support Element Functional Design

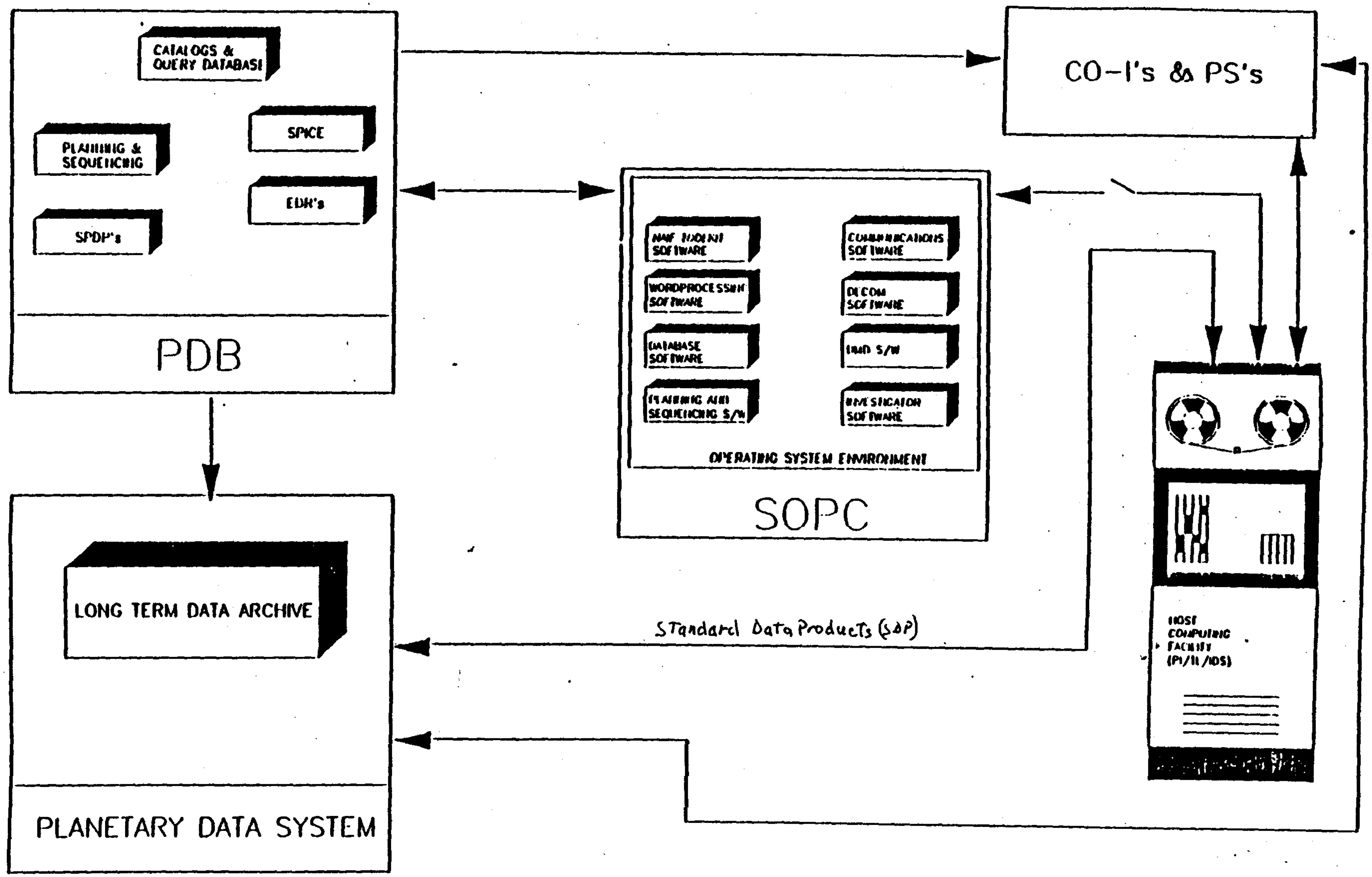


FIGURE 4.1.2 SSE DATA SYSTEM FLOW DIAGRAM

4.1.5.1 Communications

The following requirements are levied on the Communications program set:

a) The communications function shall provide an Ethernet, TCP/IP (using FTP) interface to the investigation host computer. (MOSO) [L]

b) The communication function shall provide a 56Kb modem interface (NASCOM) to the DSR Subsystem. (DSN) [L] [E]

c) The communication function shall provide the capability to transfer data between the investigation host computer(s) and the SOPC. (MOSO) [L]

d) The communication function shall provide a "pull system" (data on demand) capability to retrieve data (including channelized data) from the DSR Subsystem . (MOSO) {DSR} [L]

e) The communication function shall provide the capability to transfer data (including text files) to the DSR Subsystem . (MOSO) {DSR} [L]

f) The communications function shall provide for text file transfers between SOPCs. (MOSO) [L]

g) The communications function shall provide for a secure gateway connection path to the PDB. This function shall be in compliance with the MGS, MOSO, and NASCOM security policies ineffect. (MOSO) [L]

h) The Communications function shall provide for time-delayed data retrieval queries from the PDB accessed in a scriptable or "Batch" mode.

i) A MOSO-specific SFDU reader/writer tool shall be provided on the SOPC. (MOSO) [L]

j) A MOSO/PDS compatible Data Definition Language Tool shall be provided on the SOPC for data being transported from the SOPC to the PDB and archived in the PDS. (MOSO) {DSR} [E]

4.1.5.2 Decommutation

a) Input Requirements.

The Workstation Standalone Decommutation program set shall receive packetized telemetry, a binary decom map, and operator controls as inputs. This function will interpret, based on a decommutation map, the procedure for finding channels within the telemetry packets.

b) Functional Requirements.

The Workstation Standalone Decommutation program set shall provide the following capabilities:

1) The ability to channelize a telemetry input stream of science data packets based on the layout of these packets described in the Decommutation map. The data will be contained within an SFDU. (MOSO) [L]

2) The ability to channelize spacecraft engineering telemetry input stream based on the layout of these packets described in the Decommutation map. The data will be contained within an SFDU. (MOSO) [L]

3) The ability to write a program to interpret the data packet into channels using the Decommutation Language (DL). (MOSO) [L]

4) The ability to define channels anywhere within the header or packet information, based on several possible base (offset) addresses. (MOSO) [L]

5) The ability to use the Decommutation Map Compiler Function to compile the programs written in DL to produce a Decommutation Map. (MOSO) [L]

c) Output Requirements.

The Decommutation program set shall provide as outputs:

1) A stream or file containing selected channelized telemetry data. (MOSO) [L]

2) A list of appropriate error messages. (MOSO) [L]

4.1.5.3 Science Data Monitor and Display Requirements

a) Input requirements.

The DMD function shall receive a stream or a file of derived channel definitions, channelized science and spacecraft engineering data in SFDU format, standards and limits for a particular science instrument, and telemetry display format definitions. (MOSO) [L]

b) Functional requirements.

The DMD function shall provide the following capabilities:

1) The ability to read channelized data contained within SFDUs and extract channels from the packet data. (MOSO) [L]

2) The ability to display selected channelized engineering measurements. (MOSO) [L]

3) The ability to convert selected channels from Data Number (DN) to Engineering Units (EU). (MOSO) [L]

4) The ability to monitor selected channels for violations of alarm limits and tolerances. (MOSO) [L]

5) The ability to provide output data to a file, a CRT or a hardcopy printer. (MOSO) [L]

6) The ability to suppress display updates based upon criteria including range or delta from previous value. (MOSO) [L]

7) The DMD function shall provide the capability for an analyst to update and display the contents of the parameter controls for DMD processing. (MOSO) [L]

8) The DMD function shall provide the capability to output in different display format definitions. These will include all CRT displays as well as any defined printer output displays. (MOSO) [L]

c) Output Requirements.

The DMD function shall provide displays including:

1) Standard list type display pages showing channel number, channel name, units of measurement, current value in DN, current value in EU, any alarm conditions in yellow or red for color monitors and grey scale for monochrome monitors, along with indications of whether an alarm is a low or high excursion. (MOSO) [L]

2) Standard matrix type display showing channel number, channel name, units of measurement, current value in EU, and any alarm conditions in yellow or red for color monitors and grey scale for monochrome monitors. (MOSO) [L]

3) An alarm window in the matrix format specified in (c.2) above, with visual and audible indication to the user that an alarm has occurred. (MOSO) [L]

4) Standard plot display pages capable of plotting channel value versus time, and two different channels against each other. (MOSO) [L]

5) The ability to produce hardcopies of any of the above (c.1 through c.4) displays. This hardcopy device to be either a Laser printer or a plotter. (MOSO) [L]

d) Database Requirements.

The DMD database shall have the following contents:

Standards and limits for a particular science instrument, as well as spacecraft bus engineering. This will include measurement locations, DN to EU conversion parameters, engineering units of measurements, alarm limits, tolerance values, measurement numbers, and measurement names. (MOSO) [L]

4.1.5.4 EMail Requirements

An Electronic Mail program set shall provide for communications between the Mars Global Surveyor science community, the science users (PIs/TLs/IDSs) and the Project.

a) The EMail capability shall allow for text files produced on the SOPC to be transmitted to the DSR. (MOSO) {DSR} [L]

b) The EMail capability shall store mail for retrieval by the intended receiver. (MOSO) {DSR} [L]

c) The EMail program set shall accept text files generated by a wordprocessor. (MOSO) {DSR} [L]

d) The EMail program set shall provide for the receipt, at the SOPC, of text files retrieved at the DSR. (MOSO) {DSR} [L]

e) The EMail program shall allow for delivery of mail directly from one SOPC to another. (MOSO) {DSR} [L]

f) The EMail program set shall provide a mechanism for transferring and preparing E-Kernel inputs to the DSR. (MOSO) {DSR} [L]

g) The EMail capability shall allow for bulletin board and news services to be automatically delivered to all SOPCs from the DSR. (MOSO) {DSR} [L]

4.1.5.5 Local SOPC Database Software Requirements

The following specify the requirements for providing the capability for each of the science investigators to design the following functions for their SOPC databases.

a) The database function shall provide the ability to store information on uplink commands including: radiation time, parameter table name & number, sequence name, date, uplink window and instrument execution time. (MGS) [L]

b) The database function shall provide the capability to store information about downlink data including: day of receipt, tracking pass, associated SPICE kernels, EDRs, relevant spacecraft engineering data, health monitoring and data products. (MGS) [L]

c) The database function shall be capable of generating output reports and listings in both hardcopy and screen format. (MGS) [L]

4.1.5.6 Command Transfer Interface Requirements;

The following specify the requirements for the transfer of instrument commands, parameter table loads, and memory loads from the PI institutional computers to the PDB via the SOPC. This assumes that the science instrument commands are generated on the host computer. All data transfers to the PDB shall occur using FTP.

a) This function shall provide the interface capability to transfer instrument commands, memory loads, and parameter tables loads from the host computers to the SOPC. The transfer of such files shall be capable of being sent electronically or by physical media. (MOSO) [L]

b) This function shall provide the interface capability to transfer instrument commands, memory loads, and parameter tables loads from the SOPC, with SFDU headers, to the PDB. (MOSO) [L] [E]

c) This function shall provide an end to end error checking function. (MOSO) {DSR} [L]

d) A MOSO-specific SFDU reader/writer tool shall be provided on the SOPC. (MOSO) [L]

e) This function shall accept commands, memory loads, and parameter table loads constructed on either the SOPC or the institutional host computing resource for transfer to the PDB. (MOSO) [L]

f) This function shall accept the receipt of power profiles, in both binary and text format, from each instrument as required. (MOSO) {DSR} [L]

4.1.5.7 Command Generation Requirements

The following specify the requirements for the capability to generate instrument commands, parameter table loads, and memory loads on the SOPC by the PI.

The SOPC shall provide the capability to host PI/TL software for generating instrument commands, memory loads, and parameter tables. (MOSO) [L]

(MAG and MOLA teams generate command requests on SOPCs; MOC and TES teams use host computers.)

4.1.5.8 NAIF Requirements

The NAIF shall provide:

a) Software to access all five SPICE kernels. Mars Global Surveyor shall fully utilize the SPICE concept as a means of facilitating and updating ancillary information needed to process "raw" data into science data products. SPICE is an acronym describing the following ancillary data files called kernels including:

SPK - Spacecraft, Planet and Satellite Ephemerides.

PcK - Planet and satellite physical and cartographic constants.

IK - Instrument descriptions, including operations codes used in E Kernel and instrument alignment offset angles.

CK - Reconstructed spacecraft attitude in quaternion form, and spacecraft body rates, both relative to the J2000 inertial coordinate frame.

EK - Event information, including nominal sequences, real-time commanding, unscheduled events, and experimenter's notebook comments.

b) General purpose subroutines (referred to as "Toolkit") for use in reading the SPICE kernels and computing the investigations desired observation geometry. Included in the tool kits are: (MOSO) [L]

Vector-matrix routines for geometric applications.

Array routines

Coordinate system conversion routines

Time and reference frame conversion routines

Ephemeris reading and manipulation routines

Solar System data routines

Tri-axial and spheroidal models of Mars, Phobos, and Deimos.

Orientation of Instrument with respect to the nadir and the spacecraft velocity vector

Computation of the location of interception of a line with a body surface.

Computation of phase angle, spacecraft emission angle, and Solar incidence angle, at a body surface point specified by LAT/LONG coordinates.

Instrument-dependant coordinate conversions.

Equator crossing times.

Computation of sub-LAT/LON of the spacecraft,Sun, or other body.

Computation of slant range from the spacecraft to a point on a body surface.

Computation of the altitude of the spacecraft above a body (planet or satellite).

Computation of the state (Cartesian position and velocity vectors) of a body relative to another body.

Return the initially referenced spacecraft orientation (attitude).

Compute the inertial to body-fixed transformation. Use aberration corrections as required.

Predict Sun Earth occultation intervals based on inputs.

Compute the angular semi-diameter of a target body.

Compute the specular point on an ellipsoidal surface.

c) Capability to include Investigator inputs for the creation of E Kernels. (MOSO) {DSR} [L]

d) Capability to include Investigator inputs for the creation of I Kernels. (MOSO) {SSS} [L]

e) Capability to provide both predict and after-the-fact S&P and E kernel information. (MOSO) {DSR} [L]

f) Capability to provide for the construction of instrument C Kernels. (MOSO) [E]

g) Instrument I-Kernels. (MOSO) [L]

h) Format.

The NAIF tool set is to be provided by MOSO as a set of Fortran 77 standard C callable subroutines.

4.1.5.9 Science Workstation Hardware & System & Application Software Requirements

The following requirements specify the needs of the Science Support Subsystem levied against the Workstation, including the Project-supplied RSST workstation. Additional hardware and system software requirements are specified in the Planning and Sequencing Subsystem (Section 4.2).

a) Hardware Requirements. The hardware requirements on the SOPC workstation are specified, by investigation, in Section 3.9 of this document. Additional hardware requirements are listed below.

The hardware device shall support a multi-tasking, multi-user environment. (MOSO) [L] [E]

The hardware device shall include an Ethernet connection to the Investigation host computer. (MOSO) [L] [E]

The hardware device shall include a transportable (ie. mailable), high-capacity storage system in excess of 500 MBytes, along with a CD-ROM Reader. The hardware device shall be compatible with UNIX, VMS, DOS and Apple operating systems. (MOSO) [L] [E]

The hardware device shall include a cartridge tape unit compatible with a MOSO standard for software deliveries and upgrades. (MOSO) [L]

The hardware device shall include an electronic connection to the NASCOM-supplied modem equipment. (MOSO)[L][E]

The hardware device shall provide the capability to store at minimum, 1.5 Gigabyte of science data in addition to resident applications programs, operating system software and utilities. (MOSO)[L][E]

The hardware device shall provide the capability to run the MOSO provided software and the SEQGEN software simultaneously. (MOSO) [L]

b) System & Application Software Requirements.

The following capabilities are required of the System software:

Provide a multi-tasking, windowing environment for both the MGDS provided capabilities and the user application programs. (MOSO) [L]

Provide the ability to suspend any single task, and bring up a second task for action, specifically allowing the activation of the alarm display page during any other activity. (MOSO) [L]

Provide, as a minimum, both an ANSI standard FORTRAN 77 and a C language compiler. An additional requirement is that all compilers provided must be conversely integral. (MOSO) [L]

Provide a word processing capability, to generate instrument status reports for transmission to the Engineering Analysis Subsystem, and to provide required inputs to the I and E kernels. (MOSO) [L]

Provide device drivers for the high capacity storage, transportable media and CD-ROM devices. The SS shall be compatible with the UNIX operating systems. (MOSO) [L]

Provide a software communications capability (Ethernet) to communicate between the DSR and the investigation host computer system via the SOPC. This capability shall provide for the use of File Transfer Protocol (FTP), running on TCP/IP. (MOSO) [L]

The SS shall provide a NAIF toolkit capability (Fortran 77 Subroutine Library) to read SPICE kernels, compute observation geometry parameters, and retrieve related ancillary data in standard C-callable subroutines. (MOSO) [L]

Provide a relational database capability to include a query processor, a forms manager, and a report generator. (MOSO) [L]

Provide an interface allowing an authorized user to initiate a data retrieval process, including time delayed queries and retrieve data from the PDB in a scriptable "batch" mode. (MOSO) [L]

MOSO applications software (specified above) and SEQGEN software shall be provided.

4.1.5.10 Source, Maintenance, and Adaptation requirements.

The communications, decommutation, display, email, local databas, command generation and transfer, NAIF, system hardware, and system software functions specified above will be maintained by MOSO. Updates or changes to this software shall be tested and approved by the Mars Global Surveyor Project before being used operationally.

4.1.6 Performance Requirements;

The Science Support Subsystem shall:

a) Provide all DMD displays within one minute of the data being transferred to the SSS. This includes all required processing (decommutation, alarm checking, DN/EU conversion, etc.).

b) MGS will be responsible for the integration testing of the MGDS provided portions of the Science Workstations and the SSS workstation.

c) MGS will be responsible for the interface testing between the DSR and the Science and SSS workstation.

d) Display at least 21 different DMD channels on the matrix type display.

e) Display at least 2 different DMD plots on the plot type display.

f) Display at least 2 different time intervals on the plot type display (so as to be able to compare past performance with present performance).

g) Perform a sequential write to the WORM device at a sustained rate of 300,000 bytes per second.

h) Perform a burst data transfer rate greater than 1 MByte/sec, and an average seek time of less than 80 milliseconds for erasable optical media.

i) Perform an average read seek time of less than 400 milliseconds for a CD-ROM reader.

j) Perform a file read access to the CD-ROM reader in 200 milliseconds.

k) Perform a transfer of a catalog query over a 56 Kb NASCOM line in 5 seconds.

l) PDB access performance requirements must be met for remote SOPCs.

4.1.7 Interface Requirements

The Science Support external interfaces are provided in the following interface summary. The SSS internal interfaces are in Table 4.1.1.

INTERFACE SUMMARY - SSS RECEIVES

SIS ID	TITLE
DACE004	Archival Tracking Data Files (ATDF)
DACE005	Orbit Data Files (ODF)
DACE006	Media Calibration Data File
DACE007	Time and Polar Motion File
DACE009	Tracking Station Locations and Err File
DACE011	Raw DSN Monitor Blocks
DACE012	S/C Channelized Eng Data
DACE013	Channelized Monitor Data
DACE022	Meteorological Weather Data
DACE029	Decom Map
DACE034	Quality Quantity and Continuity (QQC) Records
DACE037	Expanded Channelized Data Record (ECDR)
DACE040	S/C Eng Telemetry Packet Data Record
DACE043	Raw Telemetry Frames
DACE044	Radio Science Open Loop SCP Data
DACE045	Radio Science Open Loop SCP Data Decom Map
DACE046	Radio Science Open Loop Data
DACE048	Browser Templates
DACE049	TDL Templates
DSR001	E-Kernel (Encounter)
*DSR004	Mag/ER Packet Data Record
*DSR005	TES Packet Data Record
*DSR006	MOC Packet Data Record
*DSR007	MOLA Packet Data Record
DSR011	Raw Data Query Results File
DSR012	QQC Summary Report File
DSR013	Database Catalog Search Results File
DSR017	Spacecraft Clock Coefficient File
EAS006	SCT System Report File

SIS ID	TITLE SSS RECEIVES (continued)
NAE002	Light Time File
NAE003	Orbit Propagation and Timing Geometry File
NAE007	Planetary Constants Kernel File
NAE008	Astrodynamic Constants and Init Cond File
NAE011	S & P Kernels
PSE001	Predicted Events File
PSE010	Spacecraft Activity Sequence File
*SSE001	I-Kernel

INTERFACE SUMMARY - SSS GENERATES

SIS ID	TITLE
DSR016	Inputs to E-Kernel (Encounter)
EAS017	Stream Data Extract Command Line Input I/F
EAS018	Database Catalog Command Line Input I/F
*SSE001	I-Kernel
*SSE004	Instrument Status Report
*SSE005	Instrument Power Profile

* = SSS Cognizant Engineer is cognizant

Table 4.1.1 SSS Internal Interfaces

File	Source	User
Decommutation Map	Decom Map Compiler	Decom
Channelized Data Stream SFDU's	Decom	DMD
TDL Binary	TDL Compiler	DMD
CCL Binary	CCL Compiler	DMD
Alarm File	DMD	Health Monitoring
Channelized Data File	DMD	Health Monitoring
User Output Display	DMD	Graphics Display
Health Monitor Report	BCE	EMail
Instrument Power Profile	BCE	EMail
Command Files	SEQGEN/BCE	SEQGEN/Command Transfer

4.2 PLANNING AND SEQUENCING SUBSYSTEM

This section presents specifications for the functional requirements and design of the Planning and Sequencing Subsystem (PSS) of the Mars Global Surveyor (MGS) Ground Data System (GDS). Much of the PSS functionality will be implemented by adapting the multi-mission sequence generation and translation software provided by the Mission Operations Support Office (MOSO), while the rest will be supported by MGS mission-unique software developed by the Project.

PSS descriptions and requirements presented in this section are organized as follows:

Section 4.2.2 - identifies the GDS functions allocated to PSS.

Section 4.2.3 - describes PSS functional design in terms of the GDS software tools used to support PSS functions.

Section 4.2.4 - specifies PSS detailed requirements at the primary functional level.

Section 4.2.5 - identifies PSS internal and external interfaces.

Section 4.2.6 - defines PSS Test requirements.

Section 4.2.7 - specifies PSS requirements allocation to the GDS delivery phases.

Section 4.2.8 - identifies PSS requirements traceability.

Section 4.2.9 - identifies applicable documents, related to PSS requirements.

PSS-specific terms used in this section are defined in Appendix B.

4.2.1 Planning and Sequencing Subsystem - Overview

The Planning and Sequencing Subsystem provides the GDS functionality necessary to support the planning and implementation of MGS science observations and engineering activities, and their transformation into complete ground and spacecraft sequences of activities in the form of groups of time ordered commands. (Functions to support transmission of commands to the spacecraft, are contained in the Data Acquisition and Command (DAC) Subsystem.) The Subsystem will be utilized by the MGS Flight Team, to perform their functions as described in the MGS Mission Operations Specification, Volume 3: Operations.

4.2.1.1 PSS Functional Capabilities

The functional capabilities supported by the Subsystem include:

a) Sequence planning, including pre-launch definition of sequences;

b) Integration of flight sequences;

c) Sequence expansion and constraint checking to support reviews and validation of sequences;

d) Generation of the binary command file to be sent to the spacecraft, loaded into memory, and executed onboard.

4.2.1.2 PSS Operational Environment

The Planning and Sequencing Subsystem provides a distributed sequencing capability, involving the MGS Flight Team. Standalone versions of the sequencing software will be installed at the SOPCs and project workstations and these will have the appropriate levels of capabilities to support the required sequencing activities. Coordination of the sequencing activities will be accomplished via the Project Data Base, which is the repository for all sequence data sets. The hardware subsystems needed to support PSS functions are described in section 3.

4.2.2 Planning and Sequencing Subsystem Functions

This section presents high-level definitions of the functions provided by the Planning and Sequencing Subsystem to support the Mars Global Surveyor planning and sequence effort.

The capabilities provided by the PSS can be grouped into five high-level functions, namely, Activity Planning, Sequence Implementation, Sequence Checking, Non-Stored Commanding, and System Security. Each of these supports a sublevel process within the sequence process for the design, checking, implementation and review of the spacecraft activities, and those ground system activities required to support the spacecraft activities. The following paragraphs specify the PSS capabilities supported by each of these five high-level functions.

4.2.2.1 Activity Planning

This high-level PSS function shall provide the capabilities required for planning the ground and spacecraft activities

a) It shall support the decision making process needed to perform the actual implementation of the sequence.

b) The decision making period shall encompass the actual generation of the values for the command parameter sets based on various planetary geometric factors, revised DSN schedules, concurrent activities, and the like.

4.2.2.2 Sequence Implementation

This high-level PSS function shall support translation of the sequencing desires defined during the activity planning period into a sequence of commands from which these desires will be accomplished by the spacecraft and supporting ground system. Sequence Implementation shall provide the following capabilities:

a) Allow modification of commands within a given Spacecraft Activity Sequence File (SASF), or generating an SASF from predefined blocks or from scratch.

b) Allow merging of multiple SASF data sets to produce a consolidated Spacecraft Activity Sequence File (SASF).

c) Expand the SASF to produce the Predicted Events File (PEF) to support sequence checking.

d) Transform the consolidated SASF to produce the Spacecraft Sequence File (SSF) that represents command-level control and emulation of the spacecraft and ground activity.

e) Translate the SSF into the binary Spacecraft Command Message File (SCMF) for transmission to the spacecraft.

f) Generate time-ordered, human-readable versions of the sequence in predefined formats for review.

4.2.2.3 Sequence Checking

This high-level PSS function shall support the following capabilities:

a) Prediction of spacecraft and ground resource use.

b) Validation of stored sequence and non-stored commands.

c) Enforcement of Project constraints as defined in Reference Document f), identified in Section 4.2.9.

4.2.2.4 Non-Stored Commanding

This high-level PSS function shall provide for requesting interactive and non-interactive commands outside of the stored sequence, and converting the requests into a form compatible with the ground command system and the spacecraft command and memory systems.

a) The support provided shall allow extensive automation of this command processing.

b) This processing shall include receipt, filtering, and generation of the requisite files for review before releasing the binary command file(s).

4.2.2.5 System Security

This high-level PSS function shall support end-to-end integrity of PSS operations by providing mechanisms for controlling access to PSS functions and authenticating user modifications to command data sets in order to prevent unauthorized changes being incorporated into the stored sequence or non-stored commands transmitted to the spacecraft.

a) System security measures shall be implemented via software in a manner transparent to authorized users.

b) System security measures shall:

b.1) Provide PSS data set protection at the user access level.

b.2) Provide Project visibility into who, when, where and how changes to the sequence were implemented. This shall provide a measure of traceability and means to perform automatic requestor validation of command and sequence requests.

b.3) Detect and report any corruption of PSS-related data sets as they are processed through the Subsystem.

4.2.3 Subsystem Functional Design

This section presents the functional design of the Planning and Sequencing Subsystem in terms of a set of primary functions, each of which provides a basic level of PSS functionality. These primary functions are:

a) Time Conversion
b) Display
c) Merge
d) Edit
e) User Interface
f) Macro Expansion
g) Check
h) Security
i) Sequence Translation
j) DSN Resource Allocation
k) Compare

In the PSS design, the capabilities required by each of the five high-level functions, identified in section 4.2.2, are supported by one or more of these primary functions. The make-up of the high-level functions in terms of the primary functions is illustrated in Table 4.2.1. In the remainder of this section, the primary functions are referred to as, simply, PSS functions. It is to be noted that while Table 4.2.1 shows the PSS functional hierarchy, the capabilities needed to fully support a high level function may be provided by other subsystems of the GDS. A good example is the security function. While the PSS primary functions CHECK and user interface provide some of the capabilities required to support security, the PDB capabilities provided by DSR are needed to fully support this function.

Each of the PSS functions shall be implemented either by using MOSO supplied multi-mission Sequence Subsystem (SEQ) software, or via mission-unique software tools developed by the Project. As specified here, the MOSO/SEQ software consists of five components, namely, SEQ_GEN, SEQ_ADAPT, COMPARE, SEQ_REVIEW and SEQTRAN. SEQ_GEN is the multi-mission software toolset for supporting sequence generation. It is designed to operate in the standard MOSO workstation multi-processing, windowed environment. This software must be adapted by the Project for MGS use. Adaptation of SEQ_GEN involves the creation of files that define the spacecraft and ground model, activity types, and flight and mission rules. This shall be accomplished using the MOSO supplied SEQ_ADAPT program. SEQTRAN is software toolset that supports sequence translation. It is operational on a SPARC workstation. This software shall be adapted by MOSO for MGS use. SEQTRAN adaptation involves software modifications to support the SCMF interface with the Data Acquisition and Control Subsystem (DAC) and development of macros to support MGS command mnemonics to bit translations and memory management. COMPARE provides the capability to compare two sequence files in order to identify differences, if any, between them.

In addition to employing adapted MOSO/SEQ software, PSS implementation involves two Project-developed software tools, MERGE, to support sequence merging and MOVTL to support the VPEF interface to the STL.

The correlation between the set of PSS primary functions and the software tools used is identified in Table 4.2.2.

Table 4.2.1 PSS Functional Hierarchy

High-Level Function	**Primary Functions Involved**
1) Activity Planning	Display, DSN Resource Allocation, User Interface
2) Sequence Implementation	Edit, Merge, Compare, Time Conversion, Display, Macro Expansion, Sequence Translation, DSN Resource Allocation, User Interface
3) Sequence Checking	Check, Time Conversion, Text Display, Graphics Display, User Interface
4) Non-Stored Commanding	Edit, Merge, CompareTime Conversion, Display, Macro Expansion, Check, Sequence Translation, DSN Resource Allocation, User Interface
5) Security	Check, User Interface

Table 4.2.2 Implementation of PSS

Function	**MOSO Subsystem**	**MGS_Tool**
(a) Time Conversion	SEQ_GEN	
(b) Display	SEQ_GEN	
(c) Merge	SEQ_GEN	MERGE
(d) Edit	SEQ_GEN	
(e) User Interface	SEQ_GEN	
(f) Macro Expansion	SEQ_GEN	MOVTL
(g) Check	SEQ_GEN, SEQ_REVIEW	
(h) Security	SEQ_GEN,SEQTRAN	DSR (PDB)
(i) Sequence Translation	SEQTRAN	
(j) DSN Resource Allocations	SEQGEN	

Figure 4.2.1 and Figures 4.2.2 present block diagrams at the highest functional level representing both the internal and the external interactions the Planning and Sequencing Subsystem provides. All data and file transfers, identified in these figures, between the PDB and user workstations are supported by the GDS Data Storage and Retrieval Subsystem (DSR).

4.2.3.1 Activity Planning

The functional design of the Activity Planning function involves the primary functions: Display and DSN Resource Allocation. They support the decision making process required to assemble the skeleton sequences, determine the geometry-driven aspects of the sequence activities, and decide how to best implement those desired activities. The specific functional capabilities they provide for performing activity planning are as follows:

a) DSN Resource Allocation supports display of MGS dedicated DSN passes.

b) Display supports displays of the Sequence Segments and Skeleton Sequences.

4.2.3.2 Sequence Implementation

Figure 4.2.2 presents the block diagram illustrating the functional design of the Sequence Implementation function. The design involves the primary functions Edit, Merge, Time Conversion, Display, Macro Expansion, constraint checking and resource tracking, Sequence Translation and DSN Resource Allocation. They support the generation of all commands used to control the spacecraft, its payload, and related ground activities. The specific functional capabilities provided by these functions are as follows:

a) Edit supports the adaptation of the skeleton sequence and the generation of SASFs.

b) Merge provides the capability to combine the user-adapted skeleton sequences.

c) Time Conversion provides the capability to relate the various spacecraft, payload and ground activities.

d) Display supports graphical and textual representations of the sequence.

e) Macro Expansion supports the generation of SSFs and PEFs.

f) DSN Resource Allocation supports the capability to provide DSN schedule display.

g) Sequence Translation translates the SSF into a SCMF.

4.2.3.3 Sequence Review

This function provides a capability to strip user specified information out of sequence products and format it for review. There is a capability for each user to specify a set of rules to apply to check the sequence products independent of SEQGEN rule checking.

4.2.3.4 Non-Stored Commanding

This function provides a route whereby commands that cannot be implemented via the nominal stored sequencing process can be checked, verified and placed in a form suitable for transmission to the spacecraft. Except for differences in the operational procedures, the process is very similar to that involved in Sequence Implementation and Sequence Checking described above.

4.2.3.5 System Security

The System Security function is intended to minimize the possibility of an unauthorized command or command group getting through the PSS and reaching the spacecraft or ground system. It involves, primarily, a set of filters and audit trails to ensure only authorized personnel/workstations may request sequence activities. It relies on a shell of functions that requires unique identification of the PSS user, merges this information into the produced file in a manner transparent to the user, and precludes non-PSS software from accessing or making changes to PSS data sets.

Figure 4.2.1 MGS Uplink Process

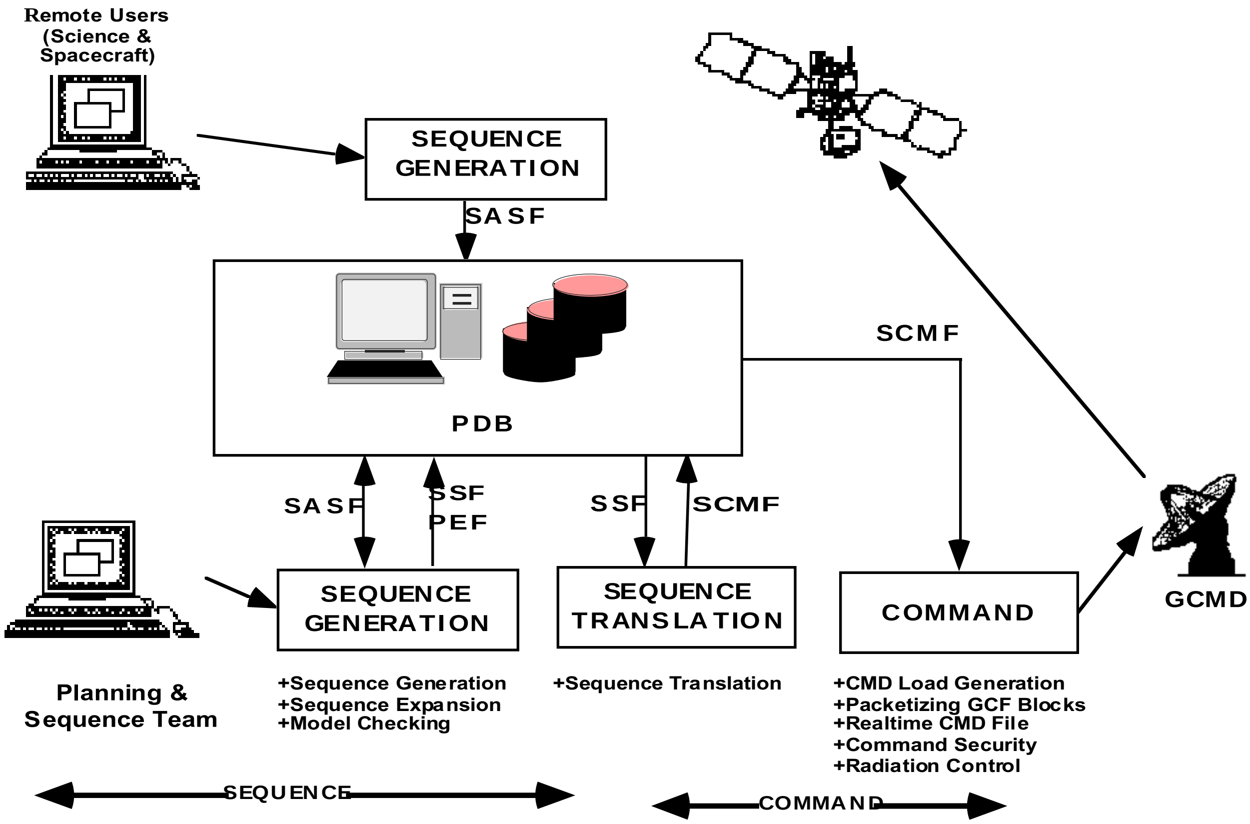
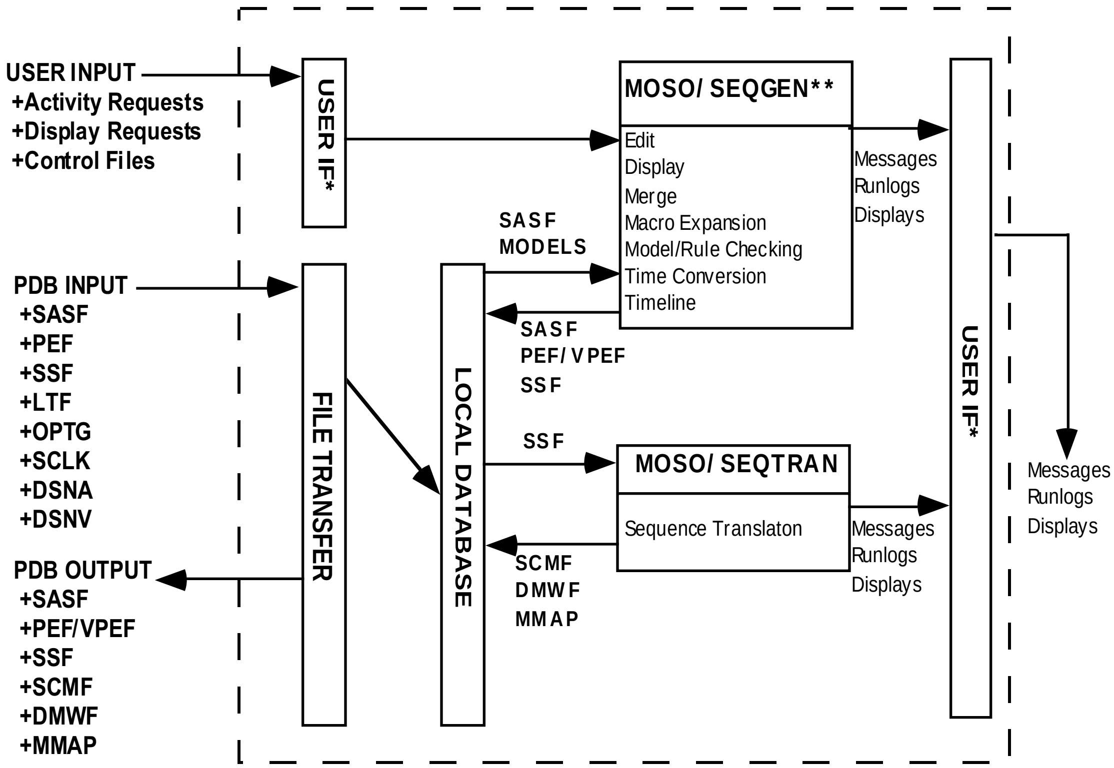


Figure 4.2.2 Sequence Implementation



* Includes keyboard, mouse and command files
** Includes MGS MERGE, REVTRAN and MOVTL

4.2.4 PSS Detailed Functional Requirements

This section presents the detailed PSS requirements at the primary functional level. As specified earlier, each PSS function will be satisfied via either MOSO supplied software, adapted for MGS use, or MGS developed software. The specific allocation of MOSO and Project produced software to these functions was presented in section 4.2.3. In this section, the emphasis will be on each PSS function itself, specifying, as a minimum, its:

a) Functional requirements;

b) Input requirements;

c) Output requirements;

d) Performance and environment requirements;

e) MOSO software adaptation requirements;

f) Development and maintenance responsibility requirements.

Specific requirements on the GDS Data Storage and Retrieval Subsystem (DSR) for supporting the required sequence data set and file transfers are provided in section 4.6 and these, therefore, are not repeated here. In addition, it is assumed that general word processing capabilities beyond those provided by the Edit function, described below, shall be supported by an off-the-shelf word processing tool and that this shall be provided as part of the workstation operational environment.

<u>PSS General Requirements</u>:

The following two general requirements are applicable to all PSS functions:

a) The functions shall be compatible with the standard MOSO workstation multi-processing, windowed environment. {PSS} (MOSO) [D]

b) Each shall be active on the local (invoking) workstation. {PSS} (MOSO) [D]

Hardware requirements for supporting these functions are described in Section 3 and they are not repeated here.

Software development and maintenance responsibility requirements specified below for each PSS function shall be governed by the MGS-MOSO interface document, identified as Reference Document c) in Section 4.2.9.

4.2.4.1 Time Conversion

This function provides the capability to convert from one time format to an equivalent time in a different format in order to relate the various spacecraft, payload and ground activities. The following conventions are used:

SCET:	Spacecraft Event Time
SCLK:	Spacecraft Clock
UTC:	Universal Time Coordinated
ERT:	Earth Receive Time (SCET plus downlink one-way-light-time)

TRM: Transmit Time (SCET minus uplink one-way-light-time)
EPOCH: A variable which can be assigned to a user specified time

4.2.4.1.1 Functional Requirements

a) Time Conversion shall display sequence time expressed in: SCET, UTC, SCLK, user local time (including automatic conversion to daylight savings time), or relative to a user specified epoch, at the user's option. (MOSO) [D]

b) Time display shall be in the MOSO time format. (MOSO) [D]

4.2.4.1.2 Input Requirements

This function shall process the following input items:

a) Light Time (LTF) File. {NAS} (MOSO) [D]

b) Conversion request from other PSS functions via electronic interface within PSS. (MOSO) [D]

c) User specified time display option. (MOSO) [D]

d) Spacecraft Clock Coefficients File (SCLK). (MOSO) [D]

4.2.4.1.3 Output Requirements

a) This function shall produce the following output:

a.1) Sequence time display expressed in the format specified by the user. (MOSO) [D]

a.2) The labelling and division of time axes with tic marks shall be automatically adjusted to the display scale following natural time divisions (e.g., 5 minutes, 10 minutes, 1 hour). (MOSO) [D]

b) The display shall use major and minor tic lengths to mark different time units (e.g., minor tics every 10 minutes, major tics every hour). (MOSO) [D]

c) Output format shall be compatible with workstation display devices. (MOSO) [D]

4.2.4.1.4 Performance/Environment Requirements

a) Conversion from one format to any other defined format shall require less than 100 milliseconds (0.1 second). (MOSO) [D]

4.2.4.1.5 Adaptation Requirements

a) This function shall be satisfied via MOSO supplied MOSO/SEQ_GEN software. (MOSO) [D]

b) Mission-specific adaptation of MOSO software shall be accomplished via MOSO supplied SEQ_ADAPT program.{PSS} [D]

4.2.4.1.6 Responsibility Requirements

a) MOSO shall be responsible for:

a.1) Providing all required functional capabilities for the Time Conversion function.

a.2) Maintenance of all related software.

b) MGS shall be responsible for:

b.1) Creation, via SEQ_ADAPT, of all control files required for Mission-specific adaptation of the MOSO/SEQ_GEN software to support the Time Conversion function.

b.2) Maintenance of the above control files.

4.2.4.2 Display

This function provides the ability to generate an electronic or hardcopy display of text and graphical data.

4.2.4.2.1 Functional Requirements.

Graphics Display shall provide all software drivers and hardware required for:

a) Video displays of text and graphic output from all PSS functions. These include:

a.1) Sequence time display as specified in Section 4.2.4.1.3. (MOSO) [D]

b) Hardcopy versions of the graphic output from all PSS functions. These include:

b.2) 'Screen Dumps' from the User Interface function (see Section 4.2.4.6.1.s) (MOSO) [D]

c) Scaling of video display to fit active screen area, when requested by the user (manually). (MOSO) [D]

4.2.4.2.2 Input Requirements

a) Graphical data for display from other PSS functions.(MOSO) [D]

b) Display routing (video, hardcopy, both) requests from other PSS functions. (MOSO) [D]

4.2.4.2.3 Output Requirements

This function shall produce the following output:

a) Video display of graphics input data. (MOSO) [D]

b) Monochrome hardcopy of graphics input data. (MOSO) [D]

4.2.4.2.4 Performance/Environment Requirements

a) This function shall produce the requested full screen, full resolution, graphic display of input data within 15 seconds of the request. (MOSO) [D]

b) This function shall produce graphic hardcopy at the rate of at least one (1) square inch per second. (80 seconds for 8 x 10 inch plot). (MOSO) [D]

4.2.4.2.5 Adaptation Requirements

a) This function shall be satisfied via MOSO supplied MOSO/SEQ_GEN software, except as noted in c). (MOSO) [D]

b) Mission-specific adaptation of MOSO software shall be accomplished by creating the required control files via MOSO supplied SEQ_ADAPT program. {PSS} [D]

4.2.4.2.6 Responsibility Requirements

a) MOSO shall be responsible for:

a.1) Providing all functional capabilities specified above for the Graphics Display function, except as noted below.

a.2) Maintenance of all related software.

b) MGS shall be responsible for:

b.1) Creation, via SEQ_ADAPT, of all control files required for Mission-specific adaptation of the MOSO/SEQ_GEN software to support the Graphics Display function.

b.2) Maintenance of the above control files.

4.2.4.3 Merge

This function allows the user to combine existing sets of sequence data to produce a consolidated data set with no redundancy.

4.2.4.3.1 Functional Requirements

The Merge function shall provide the following:

a) Combine two sequence data sets, each consisting of up to 10,000 (1 x 10E4) command/text units residing in the Local Data Base, into one data set using a basic, pre-defined merge hierarchy. (MOSO) [D]

b) The basic merge hierarchy shall use the following criteria:

b.1) When two or more identical command stems have the same time-tag, the most recently edited stem shall be retained. (MOSO) [D]

b.2) When two or more identical commands have the same time-tag, only one shall be retained. (MOSO) [D]

c) Allow optional identification of one of the data sets as being the 'control' set. When this option is active and when identical command stems/time-tags occur in both data sets, the 'control' version is retained and the other discarded.(MOSO) [D]

d) A user-specified filter to be applied to one of the data sets. Only those commands within that data set specified by the filter will be merged with the other data set. The allowable filters are:

d.1) Subsystem command stems. (MOSO) [D]

d.2) Team names. (MOSO) [D]

d.3) Support organizations. (MOSO) [D]

d.4) A window of time specified in UTC or SCET. The window may be defined by the user as either 'inclusive' (only those commands occurring within the specified window), or 'exclusive' (all except those commands). (MOSO) [D]

4.2.4.3.2 Input Requirements

This function shall process the following input items:

a) Input data set names via keyboard or command image file.{PSS} (MOSO) [D]

b) Output data set names via keyboard or command image file. {PSS} (MOSO) [D]

c) Merge hierarchy specified by user via keyboard or command image file. {PSS} (MOSO) [D]

d) Which data set is to be used as the control. {PSS} (MOSO) [D]

4.2.4.3.3 Output Requirements

This function shall produce the following output:

a) Merged data set placed in the Local Data Base. (MOSO) [D]

b) Text runlog

b.1) Listing of discarded command stems. (MOSO) [D]

b.2) Name of input and output data set(s). (MOSO) [D]

b.3) Creation date/time of output data set. (MOSO) [D] b.4) Date/time of run. (MOSO) [D]

4.2.4.3.4 Performance/Environment Requirements

a) Output data set shall be produced within 30 seconds of starting the merge. (MOSO) [D]

4.2.4.3.5 Adaptation Requirements

a) This function shall be satisfied via either MOSO supplied MOSO/SEQ_GEN software, or MGS developed software. (MOSO) [D]

b) Mission-specific adaptation of MOSO software shall be accomplished by creating the required control files via MOSO supplied SEQ_ADAPT program. {PSS} [D]

4.2.4.3.6 Responsibility Requirements

a) MOSO shall be responsible for:

a.1) Providing the functional capability in SEQGEN to merge multiple SASF's.

a.2) Maintenance of all related software.

b) MGS shall be responsible for:

b.1) Development of MERGE software.

b.2) Creation, via SEQ_ADAPT, of all control files required for Mission-specific adaptation of the MOSO/SEQ_GEN software to support the Merge function.

b.3) Maintenance of the above control files.

4.2.4.4 Edit

This function allows the user to modify or create the sequence data set contents of a specified SASF. The modification is limited to the command stem, command field and parameter values.

4.2.4.4.1 Functional Requirements

The Edit function shall satisfy the following requirements for user modification and creation of sequence request data sets (SASFs):

a) Full screen editing of the contents of an activity sequence data set in an interactive mode. The edit capabilities shall include at least the following capabilities:

a.1) Move through the file by character, parameter, record and page. (MOSO) [D]

a.2) Jump from one end of the file to the other.(MOSO) [D] a.3) Provide an 'insert' mode to allow adding data to the existing text. (MOSO) [D]

a.4) Provide a 'typeover' mode to allow replacing text with new. (MOSO) [D]

a.5) Copy a user-specified command or miscellaneous note. (MOSO) [D]

a.6) Locate the next occurrence of a user-specified character string. (MOSO) [D]

b) Creation of a user-specified Spacecraft Activity Sequence data set (SASF). (MOSO) [D]

c) Include the following header information in the modified/ created SASF:

c.1) Time of editing session. (MOSO) [D]

c.2) Workstation used. (MOSO) [D]

c.3) Name of User doing edit. (MOSO) [D]

d) The user may view, but shall not be allowed to modify, the header information, specified in c) above. (MOSO) [D]

e) Accept input of any number of different command stems, each with one (1) time tag and multiple parameter fields, for inclusion in a sequence data set. (MOSO) [D]

f) Accept input of any number of units of characters of ASCII text for inclusion in a sequence data set. Each unit will count as one (1) command. (MOSO) [D]

4.2.4.4.2 Input Requirements

This function shall process the following input data:

a) Name of SASF to be modified. {PSS} (MOSO) [D]

b) Name of output SASF. {PSS} (MOSO) [D]

c) Requestor change authority via Security Function. {PSS} (MOSO) [D]

d) MGS Command Database. {MMTI} (MOSO) [D]

4.2.4.4.3 Output Requirements

This function shall produce the following output.

a) Modified SASF to the Local Data Base. (MOSO) [D]

b) Runlog of changes made during the edit session to the Local Data Base, with user option to route to the text hardcopy function. This runlog shall include:

b.1) User ID. (MOSO) [D]

b.2) Time of Edit. (MOSO) [D]

b.3) Name of input file(s). (MOSO) [D]

b.4) Name of output file. (MOSO) [D]

b.5) Change Journal. (MOSO) [D]

4.2.4.4.4 Performance/Environment Requirement

a) Output data set shall be produced within 10 seconds of terminating the edit session. (MOSO) [D]

4.2.4.4.5 Adaptation Requirements

a) This function shall be satisfied via MOSO supplied MOSO/SEQ_GEN software, without requiring MGS modification. (MOSO) [D]

b) Mission-specific adaptation of MOSO software shall be accomplished by creating the required control files via MOSO supplied SEQ_ADAPT program. {PSS} [D]

c) The Data Storage and Retrieval Subsystem shall provide the PDB file transfer and storage/retrieval capabilities. {DSR} [D]

4.2.4.4.6 Responsibility Requirements

a) MOSO shall be responsible for:

a.1) Providing all functional capabilities specified above for the Edit function.

a.2) Providing the PDB file transfer and storage/retrieval capabilities.

a.3) Maintenance of all related software.

b) MGS shall be responsible for:

b.1) Creation, via SEQ_ADAPT, of all control files required for Mission-specific adaptation of the MOSO/SEQ_GEN software to support the Edit function.

b.2) Creation of the MGS Command Database required to accomplish the adaptation.

b.3) Maintenance of the above control files.

4.2.4.5 User Interface

This is the function by which the PSS user interfaces with the PSS functions. It provides the general shell used to invoke and direct the operation of the various PSS software functions.

4.2.4.5.1 Functional Requirements

The User Interface shall provide the following functions:

a) Selection of the following PSS operations via command line and menu:

a.1) Edit

a.2) Merge

a.3) Check

a.4) Macro Expansion

a.5) Sequence Translation (accessible by PST only)

a.7) File transfer

b) Allow execution of the above PSS operations via command image file(s). (MOSO) [D]

c) User definition of 'key macros' whereby a predefined set of keystrokes can be invoked via a single keystroke or keystroke pair. (MOSO) [D]

d) User generation of command image files, allowing at least 100 commands, with the following capabilities:

d.1) Include key macros. (MOSO) [D]

d.2) Time delays/relative time operations. (MOSO) [D]

d.3) Absolute time operations. (MOSO) [D]

d.4) User query (manual decision/data input). (MOSO) [D]

d.5) Software query (operation based on output from software function). (MOSO) [D]

d.6) Generation of audible signal. (MOSO) [D]

e) Selection of active window. (Data input by the user will be routed to the process associated with this window).(MOSO) [D]

f) Realtime definition of the size and position of the active window via:

f.1) Mouse (MOSO) [D]

f.2) Command line (MOSO) [D]

g) Provide a window that summarizes the current active and suspended (paused) PSS software. (MOSO) [D]

h) Provide file/system management functions under user control which allow:

h.1) Copying of files singly or user defined groups.(MOSO) [D]

h.2) Renaming of files singly or user defined groups.(MOSO) [D]

h.3) File deletion singly or user defined groups.(MOSO) [D]

h.4) File undelete(s). (MOSO) [D]

h.5) Moving files singly or user defined groups.(MOSO) [D]

h.6) File sorting based on name. (MOSO) [D]

h.7) File sorting based on file creation time. (MOSO) [D]

h.8) Passwords assignments to control access to PSS functions.(MOSO) [D]

h.9) Size of active memory. (MOSO) [D]

h.10) Size of free and in-use mass storage. (MOSO) [D]

i) User control of screen brightness and contrast (external access to the control(s)). (MOSO) [D]

j) Online help function to assist the user in operation of each of the software functions. (MOSO) [D]

k) Unambiguous error message when an activity fails. The message shall provide:

k.1) Type of error. (MOSO) [D]

k.2) Source of error (process or input). (MOSO) [D]

k.3) Most likely cause of error (invalid, out-of range, restricted operation, lack of memory). (MOSO) [D]

l) Automatic, non-volatile backup of the system state, including input journals for all data sets since the last save, during a session. It shall support for the following features:

l.1) The user may select the backup timing within the range of 1 to 30 minutes. (MOSO) [D]

l.2) The storage used for backup data may be released upon normal termination of the active process. (MOSO) [D]

m) A means to recover the backup input data when an abnormal termination of the process occurs (that is, system failure). This recovery shall not require more than five (5) user-input commands nor require more than five (5) minutes to accomplish. (MOSO) [D]

n) User control (when color video is used) of the screen background and foreground colors or text displays. This control shall be via manual input or command image files. Control shall not require more than five (5) user-input commands nor require more than 1 minute to accomplish. (MOSO) [D]

o) Display active PSS function in a window on the video screen.(MOSO) [D]

p) Allow at least five (5) windows to be displayed at any given time, any one of which may be active. (MOSO) [D]

q) Allow suppressing the display of any window or combination of windows. (MOSO) [D]

r) Video display shall be flicker-free. (MOSO) [D]

s) Perform 'screen dumps' to an electronic file. (MOSO) [D]

t) Perform 'screen-dumps' to the hardcopy graphics output. (MOSO) [D]

u) Allow designating one (1) workstation as a 'master' controlling the display on another workstation. (MOSO) [D]

v) Allow the user to redirect program output to a file with a user-specified name. The workstation system shall create the target file if it does not exist. (MOSO) [D]

4.2.4.5.2 Input Requirements

This function shall process the following input:

a) Name of command image file(s). {PSS} (MOSO) [D]

b) Name of key macro(s). {PSS} (MOSO) [D]

c) System command. (MOSO) [D]

d) Mouse click. {PSS} (MOSO) [D]

e) Name of target file for screen dumps. {PSS} (MOSO) [D]

4.2.4.5.3 Output Requirements

a) Display process output in assigned window. (MOSO) [D]

b) Display user input in active window. (MOSO) [D]

c) Display menu controlling the process in the active window. (MOSO) [D]

d) File of screen dumps in a format compatible with the Graphics Display function. (MOSO) [D]

e) Control characters exported to another workstation to remotely control the screen display. These control characters shall direct what is shown and how the display is configured, as well as cursor/mouse position control. (MOSO) [D]

f) Message informing the user when a user-specified target file is not empty and prompting for authorization to overwrite, or a new name. (MOSO) [D]

4.2.4.5.4 Performance/Environment Requirements

a) User input keystroke shall be displayed on the screen within:

a.1) 0.1 second (100 milliseconds) when the process is local and running alone. (MOSO) [D]

a.2) 0.2 second (200 milliseconds) when the process is local and not running alone. (MOSO) [D]

b) Shall allow at least four (4) of the PSS major functions to be active at the same time, any two (2) of the active functions may be the same. (MOSO) [D]

c) When four (4) processes are running in a multi-processing mode, the performance of the PSS software shall be at least 80% of the performance when the same software is running by itself. (MOSO) [D]

4.2.4.5.5 Adaptation Requirements

a) This function shall be satisfied via MOSO supplied MOSO/SEQ_GEN software, without requiring MGS modification. (MOSO) [D]

b) Mission-specific adaptation of MOSO software shall be accomplished by creating the required control files via MOSO supplied SEQ_ADAPT program. {PSS} [D]

4.2.4.5.6 Responsibility Requirements

a) MOSO shall be responsible for:

a.1) Providing all functional capabilities specified above for the User Interface function.

a.2) Maintenance of all related software.

b) MGS shall be responsible for:

b.1) Creation, via SEQ_ADAPT, of all control files required for Mission-specific adaptation of the MOSO/SEQ_GEN software to support the User Interface function.

b.2) Maintenance of the above control files.

4.2.4.6 Macro Expansion

This function provides the means to generate predefined groups of spacecraft and ground commands, status and notes in response to a single command. This eliminates some of the drudgery in developing sequences by allowing the Project to define the timing and relative order of commands used to accomplish standard activities.

4.2.4.6.1 Functional Requirements

The Macro Expansion function shall provide the following functions:

a) When producing an SSF, expand ground block calls into the block's defined set of commands and spacecraft block calls. Single commands and spacecraft block calls shall be passed through to the SSF without modification. (MOSO) [D]

b) When producing a PEF, expand spacecraft block calls into the block's defined set of spacecraft commands and sub-system blocks. Single commands shall be passed through to the PEF without modification. (MOSO) [D]

e) Provide input to the Check Function (when enabled) for defined constraint checking and resource tracking when producing SSF's and PEF's. (MOSO) [D]

f) Allow the use of absolute time tags and relative time tags in the block calls and controlling macros. (MOSO) [D]

g) Allow input files of at least 20,000 (2x10E4) data records.(MOSO) [D]

h) Allow output files of at least 30,000 (3x10E4) data records.(MOSO) [D]

4.2.4.6.2 Input Requirements

a) One of the following data set names:

a.1) SASF {PSS} (MOSO) [D]
a.2) SSF {PSS} (MOSO) [D]

b) Command Database file.{MMTI} (MOSO) [D]

c) User specified output data set name. {PSS} (MOSO) [D]

4.2.4.6.3 Output Requirements

a) The following data sets:

a.1) SSF (MOSO) [D]

a.2) PEF (MOSO) [D]

b) Runlog providing:

b.1) Input file name and creation date/time. (MOSO) [D]

b.2) Output file name and creation date/time. (MOSO) [D]

b.3) Messages generated by the process while running.(MOSO) [D]

4.2.4.6.4 Performance/Environment Requirements

None identified.

4.2.4.6.5 Adaptation Requirements

a) This function shall be satisfied via MOSO supplied MOSO/SEQ_GEN software, without requiring MGS modification. (MOSO) [D]

b) Mission-specific adaptation of MOSO software shall be accomplished by creating the required control files via MOSO supplied SEQ_ADAPT program. {PSS} [D]

4.2.4.6.6 Responsibility Requirements

a) MOSO shall be responsible for:

a.1) Providing all functional capabilities specified above for the Macro Expansion function.

a.2) Maintenance of all related software.

b) MGSshall be responsible for:

b.1) Creation, via SEQ_ADAPT, of all control files required for Mission-specific adaptation of the MOSO/SEQ_GEN software to support the Macro Expansion function.

b.2) Maintenance of the above control files.

4.2.4.7 Check

This function provides an automatic check of the various constraints imposed on the sequence of activities by the project and the sequence process. This includes such items as command field ranges, command density per unit time, geometry constraints, resource usage, and other restrictions that can be enforced via software. This is not a check on the user's intent, it is limited to those constraints that can be expressed in software code and those commands processed through the PSS.

4.2.4.7.1 Functional Requirements

The Check function shall provide the following:

a) Flag all occurrences of prohibited and misformatted command stems. (MOSO) [D]

b) Flag all occurrences of command field parameters which are outside the prescribed ranges. (MOSO) [FS,L]

c) Flag all occurrences of command stems in SASF data sets that were produced in workstations other than those authorized by the MGS Project. (MOSO) [FS,L]

d) Enforce the following classes of constraints:

  d.1) Command constraints. These shall include instrument commanding constraints to prevent erroneous and unauthorized commanding. (MGS) {PSS} [FS,L]

  d.2) Operational constraints. (MGS) {PSS} [FS,L]

e) Perform resource tracking. (MGS) [FS,L]

f) Generate periodic resource status information. (MGS) [FS,L]

4.2.4.7.2 Input Requirements

a) The following sequence data sets (one at a time):

  a.1) PEF {PSS} (MGS) [FS,L]

b) Files consisting of constraint model data, including:

  b.1) Sequencing constraints {PSS} (MGS) [FS,L]

  b.2) Project constraints {PSS} (MGS) [FS,L]

  b.3) Spacecraft constraints {PSS} (MGS) [FS,L]

  b.4) User constraints {PSS} (MOSO,MGS) [FS,L]

c) Initial conditions file. {PSS} (MOSO) [D]

4.2.4.7.3 Output Requirements

a) Model state(s) at user specified intervals and at the conclusion of the run in a format suitable for use as an initial conditions file for subsequent program executions. This shall support the capability to checkpoint Check process and, if required, recover from a system failure by restarting processing at the checkpoint. (MGS) [D]

b) Runlog, compatible with the Display function, listing all constraint violations. The information provided by each violation message shall be consistent with that defined in Reference Document f), specified in Section 4.2.9 below. (MGS) [D]

c) Periodic status of resources detailing instantaneous and total use as defined in Reference Document g) (see Section 4.2.9.1 below), in a format compatible with the Text Display and Merge functions. Periodic status reporting shall include the status of resources when a predetermined state, defined by the user, is reached. (MGS) [D]

4.2.4.7.4 Performance/Environment Requirements

a) Function shall accept and process a sequence data set of at least 30000 (3x10E4) command sets with 100 (10E2) known interactions (including resources) within five (5) minutes. Larger data sets shall not require more than a proportional amount of time. (MGS) [D]

4.2.4.7.5 Adaptation Requirements

a) This function shall be satisfied via MOSO supplied SEQ_GEN software without requiring MGS modification.(MOSO, MGS) [FS,L]

4.2.4.7.6 Responsibility Requirements

a) MOSO shall be responsible for:

a.1) Providing all functional capabilities specified in paragraph 4.2.4.8.1 items a, b and c.

a.2) Maintenance of all related software.

b) MGSshall be responsible for:

b.1) Creation, via SEQ_ADAPT, of all control files required for Mission-specific adaptation of the MOSO/SEQ_GEN software to support the Check function.

b.2) Maintenance of the above control files.

4.2.4.8 Security

This function provides a means to minimize the possibility of unauthorized, potentially mission fatal commands reaching the spacecraft. The function relies on two levels of protection. The first shell attempts to restrict access to data sets destined for the spacecraft (that is, commands), while the second provides an independent filter to identify commands that require special authorization before being processed.

4.2.4.8.1 Functional Requirements

The Security function shall provide the following:

a) Tracking of changes made to the PSS data sets for creation of a change genealogy. The change genealogy shall provide the following information for each session, up to a maximum of 20 sessions. (MOSO) [D]

a.1) Name and version of PSS software used. (MOSO) [D]

a.2) Name of user making change. (MOSO) [D] a.3) Log of final changes made to the data set during each Edit session. (MOSO) [D]

a.4) Date and time of session. (MOSO) [D]

a.5) Workstation used for session. (MOSO) [D]

b) The change genealogy shall be an integral part of each data set and not editable under user-control. (MOSO) [D]

c) Ensure only MGS Project-authorized users shall be able to invoke the PSS software. (MOSO) [D]

d) Ensure SSFs destined for the SEQTRAN function are produced only via PSS software. (MOSO) [D]

e) Identify system/subsystem command requests (i.e., SASFs) from non-authorized workstations. (MOSO) [D]

4.2.4.8.2 Input Requirements

a) A data set defining cognizance of the program sets and changes. This data set shall include:

a.1) Allowable command stem(s) versus workstation as defined in Reference Document e) in Section 4.2.9.1. {PSS} (MOSO) [D]

b) SASFs from the Edit function. (MOSO) [D]

c) SSF and PEF data sets from the Macro Expansion Function. (MOSO) [D]

4.2.4.8.3 Output Requirements

a) Runlog, compatible with the Display function, containing the following information:

a.1) Unauthorized command requests, including the genealogy of the data set. (MOSO) [D]

a.2) Edits done without PSSsoftware. (MOSO) [D]

a.3) Command requests classified as "restricted". {PSS} (MOSO) [D]

b) SSF data sets for the Sequence Translation function.{PSS} (MOSO) [D]

4.2.4.8.4 Performance/Environment Requirements

a) The source code, related documentation and detailed requirements relating to the PSS system security shall be classified as MO/JPL Discreet, and access controlled by the MGS Project. {PSS} (MOSO) [D]

b) PSS programs shall be provided to the Users in a compiled and/or executable form. {PSS} (MOSO) [D]

c) The function shall be transparent to the user. (MOSO) [D]

d) The function shall not result in more than a five per cent (5%) absolute increase on the performance time of the PSS function set. (MOSO) [D]

4.2.4.8.5 Adaptation Requirements

a) This function shall be satisfied via MOSO supplied MOSO/SEQ_GEN software, without requiring MGS modification. (MOSO) [D]

b) Mission-specific adaptation of MOSO software shall be accomplished by creating the required control files via MOSO supplied SEQ_ADAPT program. {PSS} [D]

4.2.4.8.6 Responsibility Requirements

a) MOSO shall be responsible for:

a.1) Providing all functional capabilities specified above for the Security function.

a.2) Maintenance of all related software.

b) MGS shall be responsible for:

b.1) Creation, via SEQ_ADAPT, of all control files required for Mission-specific adaptation of the MOSO/SEQ_GEN software to support the Security function.

b.2) Maintenance of the above control files.

4.2.4.9 Sequence Translation

The Sequence Translation function shall accept SSFs and translate the spacecraft commands contained therein into a spacecraft executable code, in the form of a SCMF, compatible with the ground command and spacecraft command and memory systems. It will also provide information as to the size of the non-stored commands, and the size and location of the stored sequence commands, as the spacecraft will store them, to support memory management.

4.2.4.9.1 Input Requirements

a) The Sequence Translation function shall accept SSFs consisting of spacecraft sequence commands as generated by the PSS. {PSS} (MOSO)

b) The function shall be controlled by user input via the user interface. {PSS} (MOSO)

c) SEQTRAN Constraint File. (MOSO)

4.2.4.9.2 Processing Requirements

a) The function shall enforce C&DH sequencing memory size restrictions as defined by the SEQTRAN Constraint File. (MOSO)

b) The function shall enforce C&DH sequencing memory use restrictions as defined by the SEQTRAN Constraint File. (MOSO)

c) The function shall generate a 'memory contents map' of the spacecraft C&DH sequencing memory for each SCMF. This map will contain the memory address and contents. (MOSO)

d) The function shall generate SCMFs in size and quantity consistent with the sequence size, spacecraft memory usage, SEQTRAN Macro Definition File, and assigned uplink windows. (MOSO)

e) The Sequence Translation function shall allow definition of a SCMF start/end time based on a TBD command in the SSF. (MOSO)

f) The function shall only process the spacecraft commands in the SSF. (MOSO)

g) The function shall produce the Spacecraft Message File compatible with the spacecraft C&DH subsystem as needed to effect the commands. (MOSO)

h) The function shall place all stored sequence commands with the same time tag in the same SCMF , unless this conflicts with the TBD command in the SSF. (MOSO)

i) The function shall place all non-stored interactive commands with the same time tag in the same SCMF . (MOSO)

j) The function shall place all non-stored non-interactive commands with the same time tag in the same SCMF . (MOSO)

k) The function shall produce an electronic log in a format compatible with the Text Function (or equivalent).(MOSO)

4.2.4.9.4 Output Requirements

a) SCMF(s) in a format compatible with the DSR for inclusion in the Project Data Base. (MOSO)

b) A runlog with the following information:

b.1) The name, date and time of creation of the input SSF.(MOSO)

b.2) The name of each SCMF generated in a session, with the following information for each:

b.2.a) Earliest allowable transmit time.

b.2.b) Nominal transmit time.

b.2.c) Latest allowable transmit time.

b.2.d) The time tag of the first and last command. (MOSO) [2/1/91]

b.3) Runtime and date. (MOSO)

b.4) SEQTRAN version used. (MOSO)

b.5) Errors encountered. (MOSO)

4.2.4.9.5 Performance/Environment Requirements

a) The function shall produce all required SCMFs and runlogs for SSF's containing 10,000 spacecraft commands within 2 hours. (MOSO)

4.2.4.9.6 Adaptation Requirements

a) This function shall be satisfied via MOSO supplied SEQTRAN software, without requiring MGS modification. (MOSO)

b) Mission-specific adaptation of MOSO software shall be accomplished by creating the required control files provided by MOSO. (MOSO)

4.2.4.9.7 Responsibility Requirements

a) This function shall be satisfied via MOSO provided software adapted for MGS use.

b) MOSO shall be responsible for all related software maintenance.

c) MGS shall be responsible for all MOSO adapted file maintenance.

4.2.4.10 DSN Resource Allocations

The DSN Resource Allocations function is used to extract for display the DSN allocations and view periods contained in the MMCT schedule.

4.2.4.10.1 Input Requirements

a) DSN schedule names from user. (MOSO) [E]

b) Start/end date, or start date and duration as user input for time period of interest. (MOSO) [E]

c) User specified durations for schedules with the following increments:

c.1) Days, for periods of 8 week schedule. (MOSO) [E]

d) User request for information from the schedule during the user-specified time period This information shall include:

d.1) Coverage from a specified DSS. (MOSO) [E] d.2) Coverage over a period of time. (MOSO) [E]

d.3) Coverage when spacecraft is not in occultation. (MOSO) [E]

d.4) Overlap periods. (MOSO) [E]

d.5) Decoded DSN configuration code. (DSN) (MOSO) [E]

d.6) Antenna type. (MOSO) [E]

e) Program control via User Interface function. (MOSO) [E]

4.2.4.10.2 Processing Requirements

The function shall provide the following capabilities:

a) Extract MGS assigned DSN allocations during the user-specified time period from the MMCT schedule(s). (MOSO) [E]

b) Generate DSN station elevation angles during each station pass. (MOSO) [E]

4.2.4.10.3 Output Requirements

a) MGS DSN schedule in a format compatible with the workstation electronic and hardcopy display and file functions. (MOSO) [E]

b) Schedules covering up to 8 weeks. (MOSO) [E]

c) X-y graphs in a format compatible with the Display function of the DSN elevation angles versus SCET and Orbit number. (MOSO) [E]

d) Tabular listings in a format compatible with the Display function of the DSN elevation angles versus SCET and Orbit number. (MOSO) [E]

4.2.4.10.4 Performance/Environment Requirements

a) Extract and produce for display the MGS DSN allocations for a 8 week schedule within fifteen (15) seconds. Longer schedules shall not require more than a proportionally longer period of time. {PSS} [E]

4.2.4.10.5 Adaptation Requirements

This function shall be satisfied via MOSO/SEQ_GEN and SEGS software without requiring MGS Modification.

4.2.4.10.6 Responsibility Requirements

a) This function shall be satisfied via MOSO provided SEGS software.

b) MOSO shall be responsible for all related software maintenance.

4.2.4.11 SEQ_GEN Adaptation Support Requirements

The MOSO provided SEQ_GEN and SEQTRAN program sets will require various amounts of adaptation before they can be used by the Mars Global Surveyor project. MGS Project is responsible for adapting SEQ_GEN and MOSO is responsible for adapting SEQTRAN. By virtue of the MOSO-SEQ software design, the MGS adaptation of SEQ_GEN will consist of the development of various database files used to guide the operation of the program. These database files will contain representations of the various constraints and resource models, range limits, special graph symbols and text formats. The data developed by PSS will be processed using MOSO supplied SEQ_ADAPT software tool to produce the format required by the SEQ_GEN program set. Additional information is contained in the MGS PSS SEQ_GEN Adaptation Specification document.

To support the SEQ_GEN Adaptation effort, the following data items and/or capabilities shall be provided to PSS by the dates specified:

a) MGS Command Database {MMTI}

b) Block and Command Dictionary (MMTI)

c) PDB File Transfer Capability {DSR}

d) Mission and Flight Rules (MGS, MMTI)

4.2.4.12 Compare Function

The compare function shall compare two nearly identical versions of SEQ or ASCII files.

4.2.4.12.1 Functional Requirements

The compare function shall be designed and controlled to compare two files of the same type within certain bounds. (MOSO) [L]

The compare function shall have five different user-selectable operating modes; SATF, SASF, SSF, PEF and ASCII. (MOSO) [L]

4.2.4.12.2 Input Requirements

This function shall process the following input data: (MOSO) [L]

a) Any two identical or nearly identical sequence data files belonging to one of the following categories:

- a.1) spacecraft activity type file (SATF)
- a.2) Spacecraft Activity Sequence File (SASF)
- a.3) Spacecraft sequence file (SSF)
- a.4) Predicted events file (PEF)

b) Any two identical or nearly identical ASCII files

c) Mask identification files, containing the names of individual parameter set masks.

d) User provided program control instruction.

4.2.4.12.3 Output Requirements

This function shall produce the following output:

a) compare log file containing: (MOSO) [L]

a.1) names of files being compared and their types
a.2) complete list of compare options selected by the user
a.3) an entry for each miscompare detected

4.2.4.12.4 Adaptation Requirements

This function shall be satisfied via MOSO supplied MOSO/COMPARE software, without requiring MGS modification.

4.2.4.12.5 Responsibility Requirements

MOSO shall be responsible for:

a) Providing all functional capabilities specified above for the COMPARE function.

b) Maintenance of all related software.

4.2.4.12.6 Performance/Environment Requirements

COMPARE shall complete the comparison of two 7200 lines PEFS with 20 miscompares in less than 15 minutes.

4.2.5 Interfaces

This section describes the internal and external electronic file interfaces required to support the PSS.

4.2.5.1 Internal

Internal interfaces within the Planning and Sequencing Subsystem are shown in Table 4.2.3. Here, EDITOR refers to the text edit utility, provided as part of the MOSO standard Workstation environment.

4.2.5.2 External

External interfaces between the Planning and Sequencing Subsystem and other MGS Data System Subsystems are shown in Appendix A.

Table 4.2.3 Mars Global Surveyor PSS Internal Interfaces

INTERFACE	FILE ACRONYM	SEQADAPT	SEQGEN	SEQTRAN
1.Conditions File	CF	.	B	.
2.Environment File	EF	R	B	.
3.Function Key Definition	FGKDF	.	B	.
4.Legend File	LF	.	B	.
5.S/C Activity Sequence File	SASF	.	B	.
6.S/C Activity Type File	SATF	B	R	.
7.S/C Model File	SMF	B	R	.
8.S/C Sequence File	SSF	.	B	R
9.User Command File	UCF	.	B	.

Legend

R = Read
W = Written
B = Both (Read & Written)

4.2.6 Test Requirements

For those portions of the PSS for which MOSO is responsible, namely, SEQ and SEQTRAN, MOSO shall perform enough unit and subsystem tests to verify and validate that these will meet the PSS functional requirements. Any adaptation of these software tools as well as the software tools developed by the Project, shall be verified by the Project in accordance with the MGS Test Engineering Management Plan (Reference Document j), identified in Section 4.2.9.1.

4.2.7 Requirements Allocations to GDS Phase

Table 4.2.4 presents the PSS requirements allocations to the GDS delivery phases. Here, multiple phase allocations indicate phased implementations.

4.2.8 Traceability

Table 4.2.5 presents the PSS requirements traceability matrix, correlating the requirement paragraph numbers with requirements specified in higher level documents (source).

Table 4.2.4 PSS Functional Requirements Allocations by Phase

Requirement	Phase
4.2.2.1 Activity Planning	FS, E
4.2.2.2Sequence Implementation:	
a) Edit	FS
b) Merge	FS
c) Sequence Expansion	FS
d) Sequence Translation	FS, L
e) Sequence Documentation	L
f) User Request Documentation	L
g) Review Products	FS, L, E
4.2.2.3 Sequence Checking:	
a) Resource Use Prediction	FS
b) Validation	FS
c) Project Constraints Enforcement	FS
4.2.2.4 Non-Stored Commanding	FS, L
4.2.2.5 System Security	L

Table 4.2.5 PSS Requirements Traceability

Para.#	**PSS Req.Summary**	**Source Doc.**	**Source Req.**
4.2.2.1	Activity Planning	MRD	4.1.8
4.2.2.2	Sequence Implementation:	.	.
	a) Edit	MRD	4.1.9
	b) Merge	MRD	4.1.9
	c) Sequence Expansion	MRD	4.1.9
	d) Sequence Translation	MRD	4.1.9
	e) Sequence Documentation	MRD	4.1.8 (Derived)
	f) User Request Documentation	MRD	4.1.9 (Derived)
	g) Review Products	MRD	4.1.9 (Derived)
	h) DSN Keywords	MRD	4.1.9 (Derived)
4.2.2.3	Sequence Checking:		
	a) Resource Use Prediction	MRD	4.1.8 (Derived)
	b) Validation	MRD	4.1.8
	c) Project Constraints Enforcement	MRD	4.1.8
4.2.2.4	Non-Stored Commanding	MRD	4.1.9
4.2.2.5	System Security	642-315 Vol.2	3.4.12
4.2.4.1	Time Conversion	MRD	4.1.9, 4.1.14
4.2.4.2	Display	MRD	4.1.9, 4.1.14
4.2.4.3	Merge	MRD	4.1.9, 4.1.14
4.2.4.4	Edit	MRD	4.1.9, 4.1.14
4.2.4.5	User Interface	MRD	4.1.9 (Derived)
4.2.4.6	Macro Expansion	MRD	4.1.9, 4.1.14
4.2.4.7	Check	MRD	4.1.8, 4.1.14
4.2.4.8	Security	642-315 Vol.2	3.4.12
4.2.4.9	Sequence Translation	MRD	4.1.9, 4.1.14
4.2.4.10	MSG DSN Resource Alloc.	MRD	4.1.9 (Derived)

4.2.9 Reference Documents

a) Mission Requirements Document (642-31)

c) MOSO Preparation Plan for the Mars Global Surveyor Mission

d) Block Dictionary and Command Dictionary / MMTI Documents

e) MGS Security Plan

f) MGS Msn/Flight Rules and Operational Constraints Definition Document

g) Resource Tracking and Status Information Definition Document

h) DSN Schedule/Allocations Document

i) SEQTRAN Functional Requirements Specification

j) Mars Global Surveyor Test Engineering Management Plan, Parts 1, 2, 3, 4.

k) 542-ST-002 STL Design Specification

4.3 NAVIGATION ANALYSIS SUBSYSTEM

This section discusses the Navigation Analysis Subsystem (NAS) of the Mars Global Surveyor Data System which is a component of the Mars Global Surveyor Mission Operations System. The design of the subsystem is defined, the requirements on the components of the subsystem are specified and the organizations responsible for satisfying the requirements are identified. These organizations include the MGS Project (Project), the Mission Operations Support Office (MOSO), and the Deep Space Network (DSN).

4.3.1 Introduction

The Mars Global Surveyor Mission requires a navigation capability in order to support the operation of the spacecraft in both planning and all flight phases of the mission. This requirement is satisfied by the Navigation Analysis Subsystem of the Data System of the Mars Global Surveyor Mission Operations System. The Navigation Analysis Subsystem will be utilized by the Mission Operations System Navigation Team to satisfy their functions as discussed in this and Volume 3 of the Mars Global Surveyor Specifications Document. Navigation software used during operations shall be generated in two stages identified as launch (L_o) and encounter (E_o). The project determined due dates for both the navigation software deliveries are:

Launch software delivery date (L_o):	3 November 1995
Encounter software delivery date (E_o):	March 1997

The functional design of the NAS is driven primarily by Navigation objectives contained in these three broad and chronological sequences:

a) During the earth-to-Mars cruise, navigate the spacecraft and deliver it at a specified time to a Mars centered aimpoint within specific error bounds,

b) During the Mars orbit insertion phase, design the MOI (Mars Orbit Insertion) propulsive maneuver such that the spacecraft is captured into a specific initial capture orbit. In addition, develop a strategy for a series of deterministic and statistical, aerobraking and propulsive maneuvers such that the mapping orbit is achieved within *a priori* errors or constraints. During the Gravity Calibration (GC) period, acquire radio tracking data in order to improve Mars gravitational field model,

c) Maintain the spacecraft's orbit within the mapping orbit configuration and constraints for the duration of the mapping and relay phases.

In addition to these and especially during the mapping phase, Navigation's task is to accurately reconstruct and predict the spacecraft's orbital motion. This is necessary for the effective analysis of on-board scientific data and the development of planning and data acquisition strategies.

4.3.2 Functional Requirements: Planning

This section addresses the functional requirements that are associated with the planning of the OD (orbit determination) and maneuver strategies and analyses that are to be utilized throughout the entire MGS operational mission. This requires an assessment of OD accuracy and a plan to maintain orbital characteristics within a priori constraints. In addition, development of propulsive maneuver strategies and their quantitative characterization (TCM's [trajectory correction maneuvers], MOI and associated orbit insertion maneuvers [Mars Orbit Insertion], areobraking, and OTM's [orbit trim maneuvers] are also required. As necessary, software models must be developed to handle analyses specifically tailored to the mission characteristics.

4.3.2.1 Orbit Determination and Error Assessment

Design characteristics of the mission impose upon the navigation process, requirements that are reflected in the spacecraft trajectory. In order to develop a navigation plan to satisfy these requirements there must exist a capability to generate spacecraft ephemerides, evaluate spacecraft orbital errors and develop strategies for improved OD accuracy throughout the mission. The required software analysis tools include:

a) ATHENA (A Theoretical Evaluation of Navigation Accuracy) [MOSO],

b) ODP (Orbit Determination Program) and DPTRAJ (Double Precision Trajectory) [PROJECT],

c) Utility programs to plot and tabularize results [PROJECT],

d) Macintosh software development and execution [PROJECT],

e) Planetary and natural satellite ephemerides and associated planetary partial derivatives along with error estimates [MOSO].

Navigation requires the utilization and continued development of the capability of ATHENA (MOSO) and a nominal (currently development ephemeris DE 234 and 325) and updated planetary ephemeris and planetary partials (MOSO).

As the Navigation software is updated to the J2000.0 Astronomical Reference System, Navigation will utilize DE-234 and DE-235 as our reference planetary ephemeris. NAS will impose accuracy requirements on the planetary ephemeris as well as due dates. The delivery of the planetary and natural satellite ephemerides on the Navigation Computer is due one year prior to launch (MOSO).

4.3.2.2 Propulsive Maneuvers

Effective navigation planning also requires capabilities to determine propulsive maneuver strategies that will produce the desired spacecraft trajectories in order to meet mission requirements.

The required software analysis tools include:

a) FAST (Fast Trajectory Analysis Program) [Project],
b) LAMBO and LAMBIC [Project],

and a series of other programs developed or applied specifically to the MGS mission [Project].

4.3.3 Functional Requirements: Analysis

This subsection discusses functional requirements that are present within the analysis function of the Navigation Analysis Subsystem. Because this software will be used in the operational phase of the mission, it will be more accurate and more inclusive in modeling phenomena influencing the spacecraft's motion, affecting data quality and the determination of orbits.

4.3.3.1 Orbit Determination

The Orbit Determination function of the Navigation Analysis Subsystem is essentially an iterative data-fitting process in which observational data are processed and reduced to enable estimates to be made of the spacecraft trajectory that best fits the observational data. Thus a capability is required to process the observational data with auxiliary calibration information (i.e. media calibrations, time and polar motion information, and tracking data corrections) and compare the processed data with data predicted from an initial estimate of the spacecraft trajectory. Furthermore, the data differences (i.e. data residuals) will be minimized using associated partial derivatives in order to estimate the initial spacecraft-state and as necessary, associated trajectory model parameters. By recomputation of the predicted data using the improved estimates, the trajectory or orbit which most closely predicts the observed data can be determined.

Unique modeling and parameter estimation requirements applicable to the MGS mission especially during the orbital phase consist of the following:

a) High Degree and Order Standard Gravity Field Model andAssociated Regression Analysis. (Project; E_o)

This is necessary because of the characteristics of the MGS mapping orbit. Analysis of radiometric data acquired from previous Mars orbiters (Mariner 9, Vikings 1 and 2) produced a 50 x 50 (degree and order) gravity field which consisted of 2500 gravity coefficients. During the orbit insertion and mapping phases, the capability to input a 50 x 50 global gravity field model is required. In addition to the unnormalized gravity field coefficients, normalized coefficients shall also be input to the gravity field model.

b) Mars Atmospheric Density Model and Dynamical Equations (Project; E_o).

The Mars atmospheric density model developed at the University of Colorado (by R. Culp and A. I. Stewart) will be the baseline model during the mapping phase and will be coded into the ODP. Input parameters, dynamical equations and solved-for quantities will be specified in a detailed memorandum. A separate atmospheric density model, MARSGRAM, shall be required for the aerobraking phase.

c) Angular Momentum Desaturation or Non-Gravitation Acceleration Model. (Project;L_o)

The time and duration of a perturbative acceleration due to angular momentum desaturation and thrusting occurring on the spacecraft will be provided to the NAS by the EAS (Reconstructed Angular Momentum Desaturation File). An appropriate model of this perturbation with the required inputs has been specified and shall be coded into the DPTRAJ and ODP. The capability to estimate this effect is also required.

d) X-Band Data and Calibrations. (Project, DAC/DSN; L_o)

The telecommunications system utilizes a single X-band frequency (uplink and downlink). All radiometric data (i.e. two-way coherent doppler, one-way doppler referenced to the USO, range, differenced doppler (F2-F3) and angular data) will be acquired at this frequency. Link calibrations and/or corrections due to the troposphere, ionosphere and as appropriate space plasma are required and will be applied to the various data types (DSN).

Tracking stations coordinates (and errors) as well as station calibrations or corrections, especially for the range data, are required as are a) the station time- delay, b) the spacecraft time-delay and c) the position offset of the center-of-mass of the spacecraft to the center-of-phase of the spacecraft's antenna(s) (DAC/DSN and EAS).

Time transformations (i.e. allow for time transformations between various measures of time used in the ODP) and polar motion corrections are required (DAC/DSN).

All radiometric data required by the NAS shall be edited and provided by a direct transfer of data files (ASCII Spacecraft Tracking Data File, ASTD) between the DSN and the NAS. In addition, tracking data files (ODF and ATDF) shall be deposited in the PDB. Accurate tracking station coordinates and an error covariance matrix are also required. (DAC/DSN; L_o)

e) Gravity Anomaly Modeling. (Project; E_o)

The modeling and estimation of gravity anomaly parameters simultaneously with gravity field coefficients is required. An upper bound on the number of gravity anomalies required is 30. Thus solve-for gravity parameters could include a 30 x 30 harmonic model plus 30 gravity anomalies simultaneously.

f) J2000.0 Epoch and Astronomical Reference System. (Project; L_o)

All Navigation software used during flight operations shall be referenced to the J2000 Astronomical Reference System.

g) Spacecraft Antenna Location and Motion Correction. (Project;L_o)

Spacecraft parameters for correcting the range and doppler data for location and the motion of the spacecraft's antenna are required from the EAS. These include the position vector of the spacecraft's center-of-mass to the phase-center of the antenna and the spacecraft's spin rate and orientation. These will be used to correct the radiometric data (an offset for the range and a spin-signature for the doppler). A model of a spinning spacecraft shall be used to account for a spin-signature in the doppler. Software shall be developed by account for spacecraft-spin and HGA-G2 gimbal effective spin during the Mars orbital phase. During interplanetary cruise, when acquiring doppler from the HGA, the spin plane is perpendicular to the spacecraft earth line-of-sight; thus a spin signature is not expected to be embedded in the doppler data.

h) Solutions Utilizing Multiple Data Arcs. (project; E_o)

Software is required to perform solutions using separate and multiple data arcs. For example, n regres files representing n data passes (i.e. data partials and calibrated data residuals) shall be combined in one accumulative solution. This is necessary because the short period of the orbiter coupled with a single tracking pass per day may make continuous long arc (several days) solutions impractical.

j) Solve-For Data Bias Parameters. (Project;L_o)

A solve-for capability for data-bias parameters is required. This is necessary whenever multiple data types are combined in a single solution.

j) Multiple and Interactive Solution Software. (Project; E_o)

A fast and efficient solution capability shall be developed perhaps by combining several ODP links (for example; Accume, Solve1 and Output). The purpose is to allow the analyst to effectively and interactively generate multiple solutions for comparative analysis. This software should operate on both the Navigation computer and the Navigation workstation. This package is similar to PSA (Pack, Solve and Analyze) which is currently used in the HEO orbit determination.

k) Software: User Friendly, Effective Interpretation and Interactive (Project; L_o).

All software shall be developed such that it is user friendly in application and results are clearly displayed and easily interpretable. Many results should have an on-screen summary with a hard copy option. Interactiveness should be utilized whenever practical and productive.

l) Doppler Residual Display. (DAC/DSN, MOSO, Project; L_o)

During mission operations, the NAS requires a real-time display of doppler and range residuals (with a hard copy capability) on a NAV workstation. The doppler residual capability already exists and shall be implemented by the Data Acquisition and Command Subsystemalong with the appropriate software for display on the Navigation workstations. This involves transfer of doppler residuals (generated by DSN software) to the PDB. The NAS shall access these files and display this data on NAS workstations using MGDS software (i.e. DMD software).

4.3.3.2 Trajectory Analysis

The Trajectory Analysis component of the Navigation Analysis Subsystem requires the capability to numerically integrate the equations of motion of the spacecraft. This includes the capability to generate a spacecraft trajectory using the spacecraft state (position and velocity) which is produced as a result of a maneuver. Note that during the orbit phase, prediction intervals for S-kernels (or SPK files) are nominally 14-21 days (173-260 orbits) and will be as long as 56 days (694 orbits) for sequence planning.

In order to accurately determine spacecraft trajectories and orbits, the modeling must account for all significant forces or accelerations acting on the spacecraft. In addition to the standard accelerations (i.e. solar radiation pressure, planetary perturbations, central body, low order gravity field, relativistic effects), other effects or perturbations must be modeled or supplemented. These include:

a) High degree and order standard gravity field model of Mars (a 50 x 50 field). (Project, E_o).

b) Mars atmosphere density model and dynamical equations of motion (Project, E_o). An additional atmospheric model, MARSGRAM, is also required for t eaerobraking part of the mission,

c) Angular-momentum desaturation model accounting for perturbative accelerations induced on the spacecraft (Project, L_o),

d) Gravity anomaly model simultaneously with standard harmonic model (Project, E_o),

e) J2000 Astronomical Reference System. Also we must have "utility" software to accept and transform launch polynomials (injection state) from 1950.0 to J2000.0 (Project, L_o) as well as to accept such information from a magnetic tape,

f) Execution of propulsive maneuvers for both inertial and pitch-over maneuvers (Project, L_o),

g) Accurate numerical integration of MGS orbits over 56 day intervals (Project, E_o).

Smaller perturbative accelerations exist such as perturbations due to Phobos and Deimos, re-radiation from the surface of Mars and a lift component of the atmospheric acceleration. Their effects are being estimated and if important they shall be included in the encounter software.

Ancillary data shall also be generated within the Trajectory Analysis component for use by other components of the NAS as well as other MOS subsystems. These include, 1) one-way light times (both geocentric and topocentric), 2) position and velocity of the spacecraft and other solar system bodies in various coordinate systems and relative to various centers, 3) time and geometry associated with geocentric occultations, 4) time and geometry associated with spacecraft eclipses, 5) time and geometry associated with equator crossings, 6) time and geometry associated with solar conjunction and 7) partial-derivatives of spacecraft encounter conditions with respect to the spacecraft state at designated epochs.

The NAS uses, but does not require, the spacecraft ground-track software (including topographic or global terrain maps) developed for MO science and mission planning activities, i.e., Mars Mapper. (Use of Mars Mapper by MGS personnel is not precluded, but such use is not suppported by the MGS Mission System office and neither the GDS nor the MOS has resources to maintain or enhance that software.)

The NAS is also responsible for the operational generation of S and P kernels (or SPK file). This shall be accomplished using NAIF supplied software as well as software to SFDU these files (MOSO). This shall be accomplished by the use of NAV supplied P-files which shall be electronically transported to the NAV workstation from the Navigation Computer. S and P kernels are generated on the Navigation workstation using NAIF software and put into the SFDU format (by MOSO supplied software) and electronically transported to the PDB (two-way transfer). This capability shall be available by the LAUNCH software delivery (MOSO,L_o). In addition, an earlier delivery of this capability (i.e. NAIF software and file transfer and SFDU software) is required for Navigation to support its development phase responsibilities (MOSO).

4.3.3.3 Propulsive Maneuver Analysis

The Maneuver Analysis component of the NAS shall have the capability to determine high precision propulsive maneuvers from estimates of the spacecraft trajectory and mission target requirements. It shall be required to support reconstruction of the propulsive maneuvers from analysis of radio tracking data.

Planning and initial or ideal propulsive maneuver parameters are required for the following:

a) Four TCM's during interplanetary cruise [Project,L_o],

b) During the Orbit Insertion phase, major propulsive maneuvers such as the MOI burn are planned. Other maneuvers include aerobraking (ABM), transfer to the mapping orbit (TMO), and one OCM (orbit change maneuver) propulsive maneuver [Project, E_o],

c) Early in the mapping phase, propulsive maneuvers will occur in order to freeze the orbital eccentricity and correct the inclination for beta-angle control. Thereafter OTM's (orbit trim maneuvers) shall occur every four to six weeks [TBR] in order to maintain the mapping orbit. New search routines must be coded into SEPV to compute the required propulsive maneuvers. [Project,E_o].

In order to accomplish each of these maneuvers, NAS requires

a) a Propulsive Maneuver Performance Data File (EAS, L_o) in order to generate the Propulsive Maneuver Profile File, and

b) a Propulsive Maneuver Implementation File (EAS, L_o).

4.3.3.4 Utilities

The Utilities component of the NAS shall act as repository for auxiliary programs used by all functions of the Navigation Team.

The capability for the management, reception, transfer and in general manipulation of various files and programs will reside in this component. Software to tabulate, graph and display trajectory and orbit determination results are also contained therein as are other programs. For example, NAVINFO is a user friendly, data base retrieval program which can generate numerical, graphical and/or pictorial output (Project,L_o).

4.3.3.5 Navigation Computer and Work Station Requirements

The currently baselined computer used by Navigation during mission operations is the Navigation Multi-Mission Computer in the Navigation Computer Facility (NCF) (Project, MOSO) (see Table 4.3.3).

A backup Navigation M/M computer is also required one year prior to launch. This computer shall also be used by the Nav Team during integration and test and during the Gravity Calibration analysis phase.

In addition, NAS requires three Sun SPARC2 and four Sun IPX workstations (Project, MOSO). Each NAS workstation requires at least 48 MB of RAM and 1 GB of hard disk storage by L-1 year. Peripheral hardware, such as laser printers, shall be in conformance with Project guidelines. Software, such as word processors, graphics capability, and DBMS are required.

4.3.4 Functional Design of Navigation Analysis Subsystem

The functional design of the Navigation Analysis Subsystem is shown in Figure 4.3.1. The baseline computer for processing Navigation data is the Navigation Multi-Mission computer. This computer system is in place. A back-up multi-mission Navigation computer shall be operational by 3 November 1995 (Project, MOSO).

The Navigation Planning function of the NAS is carried out by the program sets ATHENA and FAST and as necessary the orbit determination program (ODP). ATHENA is used for strategy design and error analysis and evaluation. This allows the navigation analyst to develop preferred strategies for orbit determination and estimate trajectory and orbital errors throughout the mission. Maneuver design requires these error estimates to design propulsive maneuvers which will satisfy mission requirements. FAST provides the means for rapidly computing spacecraft ephemerides and related information (especially K matrices) but less accurately than DPTRAJ.

The Orbit Determination function is accomplished by the program set ODP. The Orbit Determination Program (ODP) represents a mathematical and numerical model of the solar system and measurements used to navigate spacecraft. As such it performs computations relating to trajectory generation, radiometric data calculation, calibration, fitting, verification and analysis. In addition, it provides for state and multi-parameter estimation, estimate evaluation and error determination and propagation.

The Trajectory Analysis function utilizes a double precision trajectory program to numerically integrate the spacecraft's equations of motion. These are formulated using a full set of acceleration models. All physical effects influencing the spacecraft's motion must be accounted for to the extent that they impact Navigation's ability to target the spacecraft within accuracy requirements. In addition, accuracy requirements must be satisfied for orbital reconstruction and prediction purposes.

Based upon the results of the OD analysis, the trajectory analysis and generation function is to provide 1) spacecraft ephemerides, 2) timing and geometrical information associated with geocentric occultation, solar eclipses, and equatorial crossings, 3) geocentric and topocentric one-way light-time information and 4) other trajectory-type information mutually accepted as a result of interface agreements.

The Maneuver Analysis function is carried out by MOPS program set. The Maneuver Operations Program Set (MOPS) determines high precision propulsive maneuver parameters based on a selected strategy for use by the spacecraft team. The resultant output of MOPS is the Maneuver Profile File which is passed to the EAS. This file contains the ideal maneuver parameters for use in generating commandable maneuver parameter values, (i.e. the Maneuver Implementation File). Navigation and spacecraft personnel iterate on these two files until mutual agreement is reached on the execution of the propulsive maneuver.

The Utilities component of the Navigation Process contains the programs to be used by the Navigation Team for management and manipulation of the data files. In addition, software exists for the tabularization and display of Navigation results (for example, NAVINFO). The specification of utility programs will be primarily those inherited as part of the Mars Observer navigation program set.

The functional design for computations and processing done on the Navigation class 3 workstation is shown in Fig. 4.3.2.

Gravity field model solutions are nominally determined from processing done on the Navigation computer system. Solution and related files are electronically transferred to the Navigation workstation for detailed test and evaluation. The latter includes generation of a Mars geoid (and comparison with terrain), doppler residual analysis, error assessment and gravity model updates (standard modeling as well as integrating gravity anomaly models).

The atmospheric density evaluation involves the accumulation of daily atmospheric profiles developed from OD solutions. The result of this analysis will be an operational density model used by the NAV team for spacecraft ephemeris (P-file) generation. Updates to this model are expected to daily during aerobraking and weekly during mapping.

The NAS shall take the responsibility for the operational production of the S and P kernels (SPK file). This involves implementation of NAIF (Navigation Ancillary Information Facility) software on the NAV workstation, the electronic transfer of the spacecraft ephemeris (P files) from the Navigation Computer to the NAV workstation and the electronic transfer of the SP-kernels (SFDU format) to the Project Data Base. The development of software for file transfer (two-way) and SFDU headers are the responsibility of MOSO.

The planetary and natural satellite ephemerides and planetary partials files shall be delivered to the Navigation Computer one year prior to launch (MOSO). The NAS will also take responsibility for the operational generation of segmented P-kernels and transfer them to the Project Data Base. Note that when the S and P kernels are transferred to the PDB, they will be contained in a single file called the SPK file.

Other NAS components of the functional design include:

a) Spacecraft groundtrack software (includes topographic or global terrain maps) for display and operability on the Navigation workstation; with tracking schedules this will allow one to correlate doppler data acquisition with local topographic features. Thus, the Mars Mapper program, developed for MO, will be utilized on the NAV workstation (PSS, E_o),

b) DAC shall provide for doppler and range residual display on the NAV workstations with a hardcopy capability (DAC, L_o),

c) All radiometric data shall undergo an initial scrutiny by a data-conditioning-team and calibrations and corrections previously specified, shall be made available. In addition, an archival service for all radiometric data and calibrations/corrections (ATDF and ODF/ASTD) shall be provided (DAC/DSN, L_o).

The most important Navigation product is the spacecraft ephemeris or S kernel. During mapping, a reconstructed file will be generated on a daily basis from the analysis of data from a single (typically 10 hours) tracking pass. These files will be transferred to the PDB as a concatenated weekly file. For prediction, a 14-day ephemeris shall be generated on a weekly basis. This is done to satisfy the requirement of ephemeris information on-board the spacecraft. A weekly delivery of this file is necessary because of the aging process incurred throughout mission operations. Another predicted ephemeris file encompassing 56 days is required for sequencing and planning purposes. The requirement for this information shall be delineated in the Mission Requirements Document. Note that a detailed timeline for the transference of products between the various operations-teams is the responsibility of and shall appear in MOS Vol. 3 (Operations) and MOS Vol 5 (Interfaces and Operational Interface Agreements).

4.3.4.1 Requirements For File Transfers and SFDU Header Software

The following requirements are placed on MOSO and deal with the practical two-way transfer of files and information on the Navigation computer, the PDB and the Navigation workstations. These are

a) File/Information Transfer Between the PDB and the Navigation Computer.

   1. All software necessary to electronically transfer files between the PDB and the Navigation Computer are the responsibility of MOSO.

   2. All software development for any files mandated by the Project to be in the SFDU format shall be the responsibility of MOSO.

b) File/Information Transfer Between the Navigation Computer and the Navigation Workstations.

   1. All software necessary to electronically transfer files and conduct interactive sessions between the Navigation Computer and the Navigation workstations are the responsibility of MOSO.

   2. All software development for any files mandated by the Project to be in the SFDU format shall be the responsibility of MOSO.

c) File/Information Transfer Between the NAV Workstations and the PDB

1. All software necessary to electronically transfer files between the NAV workstations and the PDB are the responsibility of MOSO.

2. All software development for any files mandated by the Project to be in the SFDU format shall be the responsibility of MOSO.

d) File/Information Transfer Between the NAV Workstations and Other Project Workstations

1. All software necessary to electronically transfer files between the NAV workstations and other Project workstations are the responsibility of MOSO.

2. All software development for any files mandated by the Project to be in the SFDU format shall be the responsibility of MOSO.

e) All software developed according to the specifications in (a), (b), (c) and (d) above shall be available by L-1 year (MOSO). This is necessary for NAS to support its development phase responsibilities.

1. Any inputs required by the user to utilize the above software shall be user friendly and simple (MOSO).

2. The initiation of the file/information transfer process shall be immediate (MOSO).

3. With the completion of the file transfer process, an indication shall be presented to the user that the transfer has been successfully completed (MOSO).

f) Any file/information transferred by NAV to the PDB shall remain on the PDB (on-line or off-line) as a permanent storage facility (MOSO). In general, NAV will not maintain duplicate copies of files/information transferred to the PDB on its own database.

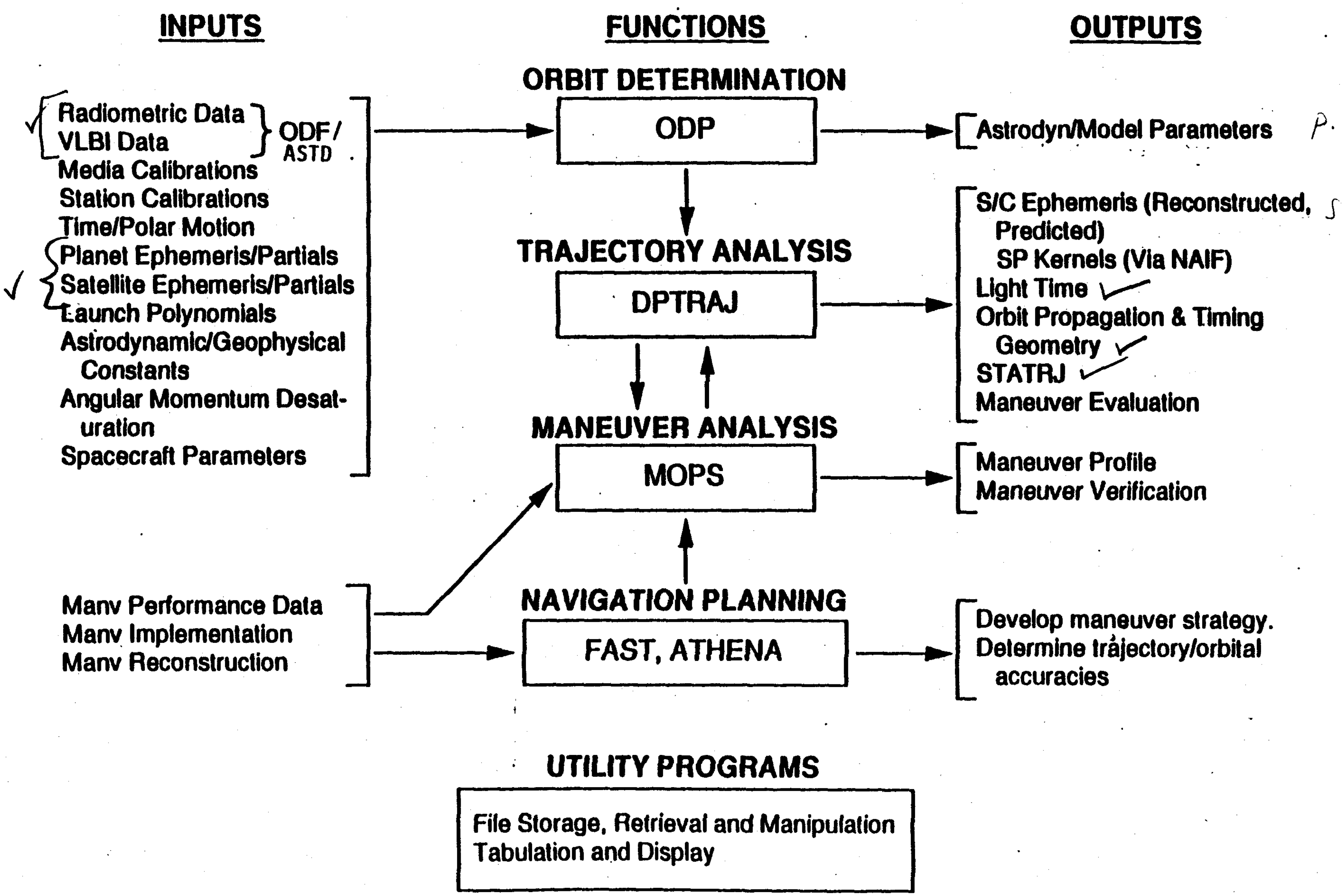


FIGURE 4.3.1 NAE Integrated Software Functional Flow, Inputs and Outputs Utilizing the Navigation Multi-Mission Computer

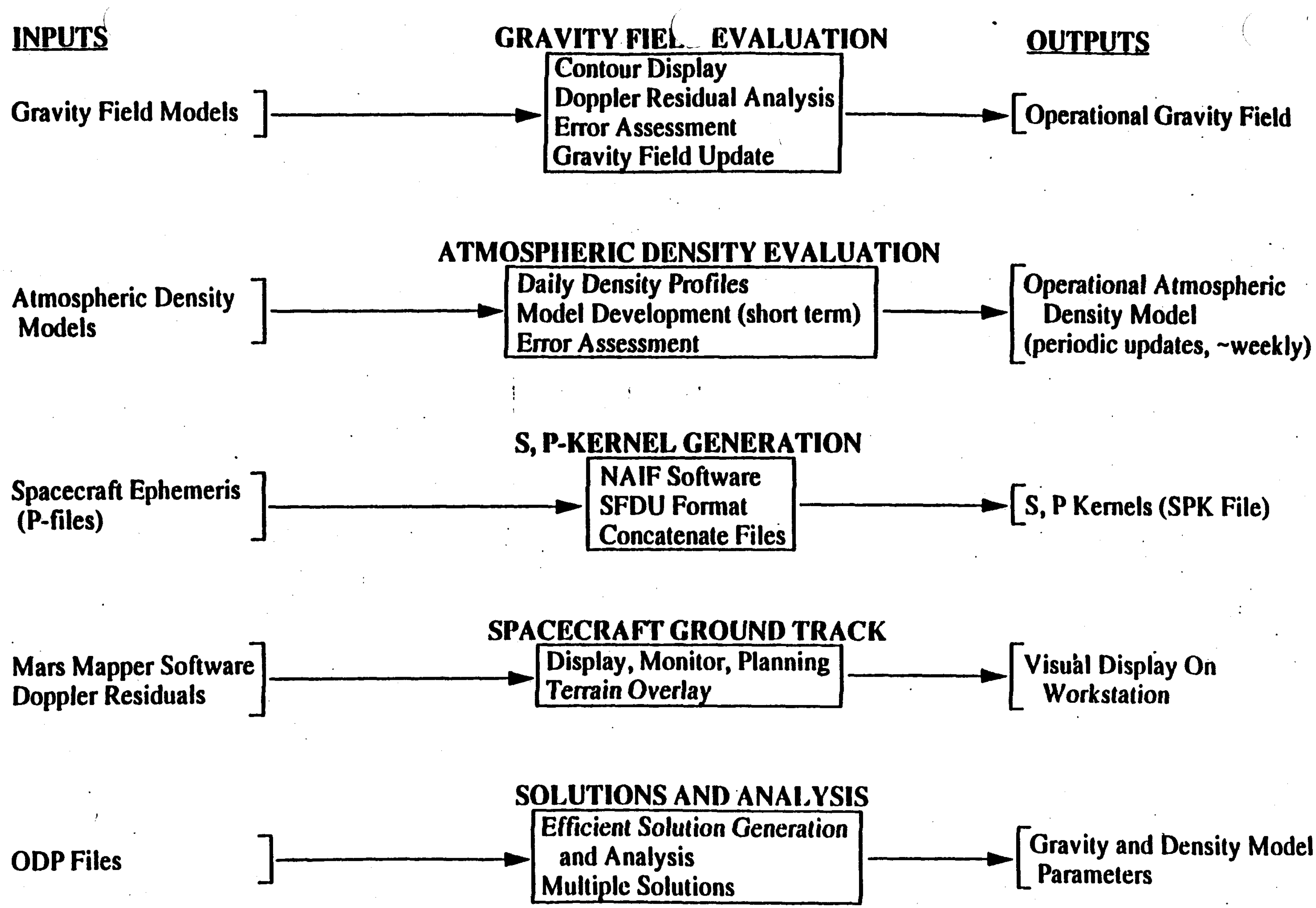


Figure 4.3.2 NAE Integrated Software Functional Flow, Inputs and Outputs Utilizing the Navigation Workstation

4.3.5 Program Set Requirements

4.3.5.1 Program Set FAST

4.3.5.1.1 Input Requirements

The input to the FAST Program set is the following:

a) Planetary Ephemeris File

b) Navigation Constants File

4.3.5.1.2 Processing Requirements

The FAST program set shall integrate the differential equations of motion of the spacecraft faster than DPTRAJ, but with less accuracy (i.e. so- called medium accuracy). The program shall also perform a variety of searches on sets of control variables to achieve targeting within specified constraints.

4.3.5.1.3 Output Requirements

The output from the FAST program set shall be the following:

a) Medium accuracy Spacecraft Ephemeris File (P-file)

b) FAST State File

c) FAST K-matrix File

d) ATHENA Interface File

4.3.5.1.4 Source, Maintenance and Adaptation Requirements

The FAST function software is required by NAS and shall be fully integrated within the NAS. Maintenance support of FAST shall be solely the responsibility of the Project.

4.3.5.2 Program Set ATHENA

4.3.5.2.1 Input Requirements

The input to the ATHENA program set shall be the following:

a) ATHENA Interface File from FAST

b) FAST State File

c) Planetary Ephemeris File

d) Planetary Ephemeris Partial Derivative File

e) Data quantity, quality, and type as specified by the orbit determination analyst.

4.3.5.2.2 Processing Requirements

Navigation Planning shall perform an error analysis by computing error covariance matrices and comparing the uncertainties with the design parameters as specified in the Mission Requirements Document.

4.3.5.2.3 Output Requirements

The output shall be the error covariances that can be used for input to the ADAM program set and reviewed by the orbit determination analyst.

4.3.5.2.4 Source, Maintenance and Adaptation Requirements

The ATHENA functional and development responsibility resides with MOSO with planning/operational requirements input by the NAS; it shall be fully integrated within this subsystem. Maintenance support of ATHENA shall be solely the responsibility of MOSO. Adaption requirements are the J2000.0 ARS, the capability to estimate 500 parameters simultaneously and to use Phobos and Deimos ephemerides in error studies.

4.3.5.3 Program Set LAMBO

4.3.5.3.1 Input Requirements

The Inputs required for the LAMBO program set are:

a) Orbit determination covariances at maneuver epochs from the Salient Information File generated by the ODP.

b) Maneuver execution error parameters from the Mission Requirements Document.

c) Candidate maneuver times, targets, and strategies from the maneuver analyst on the Downlink Operations Team.

d) A K-matrix File obtained from either the Trajectory Analysis component or the Navigation Planning component of the Downlink Operations Team.

e) Maneuver Performance Data File

4.3.5.3.2 Processing Requirements

LAMBO is a Monte Carlo simulation program that will compute trajectory maneuvers and associated statistics.

4.3.5.3.3 Output Requirements

The output of LAMBO shall:

a) Statistics of expected delta-V requirements.

b) Statistics of expected delivery conditions associated with chosen maneuver strategies and orbit determination.

4.3.5.3.4 Source, Maintenance and Adaptation Requirements

The LAMBO function shall be the responsibility of the NAS. Maintenance support of LAMBO shall be solely the responsibility of the Project.

4.3.5.4 Program Set ODP

4.3.5.4.1 Radio Metric Data Processing

The processing of observed radiometric data requires a computational estimate of that data (i.e. computed data). This in turn directly depends upon the mathematical/numerical model to faithfully reproduce the motion of the spacecraft and accurately calibrate or correct the data for a variety of media, station and spacecraft effects (e.g. earth troposphere and ionosphere, interplanetary plasma, tracking station and spacecraft time-delays for range data, spacecraft antenna offsets and motions with respect to the center-of-mass of the spacecraft, etc.). Once all this information is properly applied, data residuals (observed data minus calculated data) can be generated from which the analysis of trajectory and orbital motion proceeds.

4.3.5.4.1.1 Input Requirements

The computation of radiometric data and the application of calibrations and corrections (from which data residuals are generated) require the following inputs:

a) Radiometric Data File also called Orbit Data File (ODF or ASTD).

b) deleted.

c) Media Calibration Data File (troposphere, ionosphere and space plasma).

d) Timing and Polar Motion File (STOIC).

e) Station Locations and Calibration File.

f) Navigation Constants File (GIN)

g) Navigation Engineering Information File (spacecraft mass, component areas, reflectivity coefficients, etc.)

h) Planetary and Natural Satellite Ephemeris Files.

i) Planetary and Satellite Ephemeris Partial Derivative File.

j) Post Maneuver State Estimation File.

A most important intermediary output product from the utilization of these inputs by the trajectory/orbit generation component of the ODP is the Spacecraft Ephemeris and Partial Derivative File (PV FILE). Finally the calibrated/corrected data residual file is the output of this process.

4.3.5.4.1.2 Processing Requirements

Effective models for the spacecraft's motions (i.e. motion due to external sources as well as those due to internal sources such as HGA induced motion or spacecraft rotation) shall be implemented in the software in order to accurately calculate observables or data measurements. Also the data measurements must be calibrated and/or corrected for all the effects mentioned above.

Partial derivatives of the observables with respect to the parameters to be estimated shall also be generated with the above files. These are necessary for the ensuing OD analysis, determination of model parameters and the generation of reconstructed and predicted trajectories and orbits.

4.3.5.4.1.3 Output Requirements

The output of the radiometric ~~and VLBI~~ data processing shall be a set of data measurement residuals and partial derivatives of observables with respect to estimated parameters.

4.3.5.4.1.4 Source, Maintenance and Adaptation Requirements

The ODP function of processing radio metric data from an Orbit Data File (or ASTD file) shall be the responsibility of the NAS and shall be fully integrated within this Subsystem. Maintenance support shall be solely the responsibility of the Project. Adaptation requirements are the following:

a) Upgrade of the Astronomical Reference System from the B1950.0 to the J2000.0 system.

b) Development of software that will process X-band (uplink and downlink) radiometric data.

c) Development of the capability to process the parameters in the DPTRAJ model that account for the angular momentum, reaction-wheel desaturation effects.

d) Development of software that will allow a high degree and order Mars gravity field (50 x 50 to be input to DPTRAJ). In addition these coefficients must be capable of being estimated. The estimate capability shall include all gravity coefficients of a 30 x 30 global gravity field model.

e) Development of a Mars atmospheric density model with the corresponding perturbative equations of motion and a parameter estimation capability.

f) Development of estimation software capable of the simultaneous solution of 1000 parameters.

4.3.5.4.2 Spacecraft State Estimation Process

4.3.5.4.2.1 Input Requirements

The input to the Spacecraft State Estimation Process shall be a set of measurement residuals and their partial derivatives with respect to the parameters to be estimated and considered.

4.3.5.4.2.2 Processing Requirements

The data residuals shall be analyzed, using associated partial derivatives, to estimate the initial spacecraft state, and as necessary trajectory model parameters (gravity field coefficients, atmospheric drag parameters, etc.) and a variety of non-dynamic parameters (station location coordinates, data biases, etc.). Three methods may be used in obtaining these solutions. These are the single batch, the sequential filter, and the smoothed solution modes. These methods are based on the square root information array formulation using Householder transformations to compactly represent the information content of the data. Solutions are obtained using singular value decomposition with options to obtain less than full rank solutions and to determine numerical properties.

In the single batch mode all of the data are used to form an information array and residual vector. This model allows the user to include the effects of parameters other than those being estimated (i.e., consider parameters).

In the sequential filter mode, certain parameters which affect the spacecraft motion (e.g., sporadic gas leaks) are modeled either as a white noise sequence or as an exponentially correlated stochastic process and are referred to as dynamic stochastic parameters. Bias parameters, such as station location errors or more directly, data biases, shall also be modeled.

In the smoothing mode, solution batches are received from the sequential filter mode and used with all of the data spanning all batches.

The choice of the mode is dependent on prevailing spacecraft environmental conditions (e.g., gas leaks, unbalanced thrusting, failed reaction wheel, etc.).

4.3.5.4.2.3 Output Requirements

The output solutions shall include an improved spacecraft state estimate and, as necessary, associated trajectory model parameters. These results shall be contained in the Salient Information File. In addition, the results of this process shall be user friendly and interactive. The analyst shall have available screen displays summarizing solutions, data and data residuals as well as hard copy. User interaction can take the form, for example, of deleting data to produce a new solution or updating the GIN file to start a new iteration.

4.3.5.4.2.4 Source, Maintenance and Adaptation Requirements

The ODP State Estimation Process shall be the responsibility of the NAS and shall be fully integrated within NAS. Maintenance support shall be solely the responsibility of the Project. Adaptation requirements have been summarized previously.

4.3.5.5 Program Set DPTRAJ

4.3.5.5.1 Spacecraft Trajectory Generation

4.3.5.5.1.1 Input Requirements

The Trajectory Analysis component of the NAS shall be able to read the following files:

a) Navigation Constants File (GIN)

b) Planetary and Natural Satellite Ephemeris File

c) Planetary and Satellite Ephemeris Partial Derivative File

d) Maneuver Verification Data File

e) Spacecraft Angular Momentum Desaturation Data File

4.3.5.5.1.2 Processing Requirements

The primary Spacecraft Trajectory Generation function of the DPTRAJ program set shall be to numerically integrate the differential equations of motion of the spacecraft to produce a Spacecraft Ephemeris File. This is accomplished by program PVDRIVE. In addition, program PVDRIVE numerically integrates a specified set of spacecraft acceleration models and acceleration variations to predict the spacecraft state and the spacecraft-state partials with respect to spacecraft initial conditions, astrodynamic parameters, and force model parameters.

DPTRAJ shall have a secondary function involving the Maneuver Analysis component of the NAS; that is to generate a spacecraft trajectory using as initial conditions the spacecraft state (position and velocity) produced as a result of a maneuver. These initial conditions are obtained from Maneuver Analysis through the Maneuver Verification Data File.

4.3.5.5.1.3 Output Requirements

The primary output of the Spacecraft Trajectory Generation function shall be the Spacecraft Ephemeris File. However note that during the mapping phase, the spacecraft is a short periodic orbiter. A fourteen day (173 orbits) prediction interval is standard; however 21 day and 56 day prediction intervals will also be required. The accuracy of the numerical integrator, over these intervals, must be evaluated.

The NAVINFO program shall be utilized to provide tabular and graphical output for a variety of geometric and orbital quantities which are important in the analysis.

4.3.5.5.1.4 Source, Maintenance and Adaptation Requirements

The Spacecraft Trajectory Generation function shall be the responsibility of the NAS and shall be fully integrated within this subsystem. Maintenance support shall be solely the responsibility of the Project. Adaptation requirements are the following:

a) Upgrade of the Astronomical Reference System from the B1950.0 to the J2000.0 system.

b) Development of software that will process 1000 dynamic parameters.

c) Development of a model that describes the effects of angular momentum reaction-wheel desaturation on the spacecraft.

d) Development of software that will model high degree and order gravity fields (50 x 50). In addition, all coefficients for a 30 x 30 model must be capable of being estimated.

e) Development of a Mars atmospheric density model with the corresponding equations of motion and a parameter estimation capability.

f) Development of software that can model a constant pitch-rate maneuver and include the maneuver-defining parameters as possible control variables in trajectory targeting capabilities.

g) Development of software to design orbit trim maneuvers (OTMs) to maintain the mapping orbit.

h) Development of software to design OTMs for freezing the mapping orbit. The target elements may be the semi-major axis, node, eccentricity, argument of periapsis or the inclination of the orbit.

4.3.5.5.2 One-Way Light-Time Computation

4.3.5.5.2.1 Input Requirements

The One-Way Light-Time (OWLT) computation function of the DPTRAJ program set shall require the Planetary Ephemeris File and the Spacecraft Ephemeris File.

4.3.5.5.2.2 Processing Requirements

DPTRAJ shall generate OWLT Files using the DPTRAJ program LITIME. It shall produce earth-centered and topocentric light times. The accuracy shall be less than or equal to $2x10^{-3}$ seconds.

4.3.5.5.2.3 Output Requirements

The output shall be the OWLT File.

4.3.5.5.2.4 Source, Maintenance and Adaptation Requirements

The OWLT computation function of DPTRAJ shall be the responsibility of the NAS and shall be fully integrated within NAS. Maintenance support shall be solely the responsibility of the Project. Adaptation requirements include the generation of topocentric as well as geocentric light times.

4.3.5.5.3 Trajectory Model Data Base Maintenance

4.3.5.5.3.1 Input Requirements

The Trajectory Model Data Base Maintenance function of the DPTRAJ program set shall be able to read the following files:

a) Spacecraft Ephemeris File (P-File)

b) Navigation Constants File (GIN)

c) Planetary and Satellite Ephemeris File

d) Timing and Polar Motion File

4.3.5.5.3.2 Processing Requirements

DPTRAJ transforms spacecraft ephemerides into the following forms:

a) TWIST Save File - This file shall contain geometric positions and velocities of the spacecraft in various coordinate systems and relative to various coordinate centers. It shall be generated by the DPTRAJ program TWIST.

b) Orbit Propagation Timing Geometry File (OPTG) - This file shall contain event times and geometry for 1) apoapsis and periapsis, 2) heliocentric and geocentric occultations, and 3) equatorial crossings and polar passages, 4) solar eclipses, 5) atmospheric density and dynamic pressure as well as other information established through requirements and/or interface agreements.

4.3.5.5.3.3 Output Requirements

The output shall be those files listed in the processing subsection above.

4.3.5.5.3.4 Source, Maintenance and Adaptation Requirements

The Trajectory Model Data Base Maintenance function of DPTRAJ shall be the responsibility of the NAS and shall be fully integrated within NAS. Maintenance support shall be solely the responsibility of the Project. Adaptation requirements have been summarized previously.

4.3.5.5.4 DPTRAJ: K-matrix Generation

4.3.5.5.4.1 Input Requirements

The DPTRAJ program SEPV shall be able to read the Navigation Constants File (GIN) and the Planetary Ephemeris File.

4.3.5.5.4.2 Processing Requirements

DPTRAJ program SEPV shall numerically integrate the spacecraft trajectory equations and variational equations.

4.3.5.5.4.3 Output Requirements

The output of the numerical integration process by DPTRAJ program SEPV shall be a K-matrix File, which consists of partial derivative matrices of spacecraft encounter conditions with respect to the spacecraft state at designated epochs.

4.3.5.5.4.4 Source, Maintenance and Adaptation Requirements

The DPTRAJ K-matrix Generation function shall be the responsibility of the NAS and shall be fully integrated within NAS. Maintenance support shall be solely the responsibility of the Project.

4.3.5.6 Program Set MOPS

4.3.5.6.1 Input Requirements

The Maneuver Operations Program Set shall require the following inputs:

a) Spacecraft Ephemeris File

b) Salient Information File

c) DPTRAJ K-matrix File

d) FAST State File

e) FAST K-matrix File

f) Manual input of mission and target conditions as specified by mission design or navigation studies or project guidelines.

g) Maneuver Implementation/Reconstruction File.

h) Maneuver Performance Data File.

4.3.5.6.2 Processing Requirements

The Maneuver Operations Program Set shall compute the precision maneuver parameters according to the selected maneuver strategy. The determination of the parameters requires the computation of the delta-V vector, maneuver start time and burn time. In addition, various auxiliary data shall be computed to provide performance information associated with the maneuver, including maneuver evaluation products.

4.3.5.6.3 Output Requirements

a) Maneuver Profile File.

b) Precision maneuver data shall be provided in a Maneuver Verification Data File.

c) Post-maneuver state, epoch, and covariance shall be supplied in the Post-Maneuver State Estimates File.

4.3.5.6.4 Source, Maintenance, and Adaptation Requirements

The MOPS function shall be the responsibility of the NASand shall be fully integrated within NAS. Maintenance support shall be solely the responsibility of the Project.

4.3.5.7 AND 4.3.5.8 DELETED

4.3.5.9 Program Set UTILS

4.3.5.9.1 Input Requirements

The Utilities program set UTILS shall be capable of reading the following:

a) Navigation data files and tapes in a variety of formats.

b) Control statements to execute selected utility programs.

4.3.5.9.2 Processing Requirements

The program set UTILS shall:

a) Transform data from one coordinate system to another. Provide tabular and graphical displays of a variety of geometric and orbital quantities.

b) Expand control statements for file manipulation into more complex sets of executive instructions.

c) Update and edit existing data files.

d) Provide graphics capability to plot atmospheric density and variations, dynamic pressure, orbit elements, and other geometric quantities especially throughout aerobraking.

4.3.5.9.3 Output Requirements

Output products of the utility programs must correctly interface with the Navigation Analysis Subsystem software. The output shall consist of the following:

a) Formatted print of the contents of files or tapes.

b) Files or tapes containing reformatted or updated data.

c) Display of expanded computer system control language statements.

4.3.5.9.4 Source, Maintenance, and Adaptation Requirements

The UTILS function shall be the responsibility of the NASand shall be fully integrated within NAS. Maintenance support shall be solely the responsibility of the Project. Adaptation requirements will stress screen displays and user-interaction to display necessary information. The UTILITY program set shall be that inherited from the Mars Observer Project.

4.3.6 Performance Requirements

The following performance requirements are estimates of runstream setup time, computer execution times (expressed as Unisys SUP's or standard unit of processing) and analyst analysis-time. These units are currently being used because the baseline computer for Navigation operations was IPC's (Information Processing Center) Unisys system and this forms the basis of our current experience. These estimates were taken from Mars Global Surveyor representative computer runs made during the current development phase.

4.3.6.1 Program Set FAST

Program set FAST shall generate less precise spacecraft ephemerides and K- matrices compared to DPTRAJ, but with much faster turn-around times.

Runstream Setup (min.):	20
Run execution time (min.):	30
Printout (min.):	15
Analysis (min.):	20

4.3.6.2 Program Set ATHENA

Program set ATHENA shall provide statistical parameters for analyzing new strategies to achieve accurate orbit determination.

Initial Runstream Setup (hrs.):	8
Run execution time (hrs.):	5
Initial Printout (min.):	50
Analysis (min.):	60
File Copy to Storage Device (tape) (min):	45

4.3.6.3 Program Set LAMBO

Program set LAMBO shall compute trajectory maneuvers and associated statistics in the following amounts of time after receipt of its inputs from the maneuver analyst:

Runstream Setup (min.):	20
Run execution time (min.):	10
Printout (min.):	5
Analysis (min.):	20

4.3.6.4 Program Set ODP

4.3.6.4.1 Radio Metric Data Processing

Data residuals shall be computed by the ODP program REGRESS in the following amounts of time after receipt of the Orbit Data File. The following program links are to be executed: GIN, TRANSLATE, PVDRIVE, REGRESDRIVE and EDIT.

	Cruise	Mapping Orbit
Runstream Setup (min.):	20	20
Run execution time (min.): (single data pass)	10-30	90
Printout (min.):	20	30
Analysis (min.):	40	60
File Copy to Storage Device (min.):	20	20

4.3.6.4.2 Spacecraft State Estimation Process

A Salient Information File shall be generated by the ODP in the following amounts of time after computation of the data residuals. The following program links are to be executed: ACCUMDRIVE, SOLVE1, OUTPUTDRIVE, MAPGEN and MAPSEM.

	Cruise	Mapping Orbit
Runstream Setup (min.):	15	15
Run execution time (min.): (single data pass)		20
Printout (min.):	20	30
Analysis (min.):	60	60
File Copy to Storage Device (min.):	20	20

4.3.6.5 Program Set DPTRAJ

4.3.6.5.1 Spacecraft Trajectory Generation

A Spacecraft Ephemeris File (P-file) shall be generated in the following amounts of time after receipt of initial conditions from the orbit determination analyst. The example for this case was a 14 day trajectory with a 20 x 20 standard gravity model supplemental by 15 gravity anomalies in the converged state and with "Priority 1" access to the computer. The following program links are to be executed: GIN, PDRIVE and TWIST.

Runstream Setup (min.):	30
Run execution time (min.):	120-150
Printout (min.):	20
Analysis (min.):	60

4.3.6.5.2 One-Way Light Time Generation

The One-Way Light Time File shall be generated in the following amounts of time after receipt of initial conditions from the orbit determination analyst:

Runstream Setup (min.):	5
Run Execution Time (min):	15
Printout (min):	15
Analysis (min.):	0

4.3.6.5.3 Other Trajectory-Dependent Products

a) TWIST File -

Runstream Setup (min.):	5
Run Execution Time (min.):	15
Printout (min:):	20
Analysis (min.):	15

b) STATRJ File -

Runstream Setup (min.):	5
Run Execution Time (min.):	30
Printout (min.):	15
Analysis (min.):	15

c) Orbit Propagation, Timing and Geometry File -

Runstream Setup (min.):	5
Run Execution Time (min.):	15
Printout (min):	15
Analysis (min.):	15

4.3.6.5.4 DPTRAJ K-Matrix Generation

The DPTRAJ K-matrix generation shall be accomplished in the following amounts of time after the initial conditions are received from the orbit determination analyst:

Runstream Setup (min.):	5
Run Execution Time (min.):	60
Printout (min.):	15

Analysis (min.):	20

4.3.6.6 Program Set MOPS

The program set MOPS shall produce precision maneuver parameters in the following amounts of time after receipt of the selected maneuver strategy:

Runstream Setup (min.):	60
Run Execution Time (min.):	75
Printout (min.):	30
Analysis (min.):	15

4.3.6.7 DELETED

4.3.6.8 DELETED

4.3.6.9 Program Set UTILS

The UTILS program set must execute within seconds to tens of seconds after receipt of inputs from the analyst.

4.3.6.10 Gravity Cal (GC) and Model Development

This section addresses the operational timeline requirements for completing the GC-gravity field analysis. Starting immediately after the GC data are acquired, 30 working days (maximum) have been allocated for the determination of the 30 x 30 Mars gravity field. The following table gives the end-to-end times (i.e. from run submission to run completion) required for this analysis. Cases are shown as a function of orbit blocks (i.e. 12 orbits or 1 day), doppler count- time and the total quantity of doppler expected during the corresponding block.

Orbit or Data Block/ Doppler Count-Time and Quantity	End-to-End Completion Time	Priority
24 hours/30 sec, 1920	2 hours	1
7 days/30 sec, 13440	15 hours	2
7 days/10 sec, 40320	40 hours	3

The following procedure is an initial assessment of the operational determination of the gravity field:

a) Determine a reduced gravity field (20 x 20) using the short-arc technique

1) Analyze doppler (30 sec count-time) in one day blocks,

2) Accumulate seven data blocks,

3) Solve for 20 x 20 gravity field,

4) Converge the solution; it is estimated that five iterations will be necessary.

b) Determine the full gravity field (30 x 30) using the short-arc technique (use results from above)

1) Analyze doppler (30 sec count-time) in one day blocks,

2) Accumulate seven data blocks,

3) Solve for 30 x 30 gravity field,

4) Converge the solution; it is estimated that five iterations will be necessary.

c) Determine the full gravity field (30 x 30) using the long-arc technique

(use results from above)

1) Analyze entire seven days of doppler (30 sec count-time) as a single data block,

2) Solve for 30 x 30 gravity field,

3) Converge the solution; it is estimated that five iterations will be necessary.

The GC data acquisition and analysis schedule is as follows:

Data Acquisition		Data Analysis (30 working days)	
1-1-98 GC Start	1- 12-98 GC End	Note: 4 days of the data acquisition phase shall be used for analysis Delivery	Gravity Field

The determination of the 20 x 20 gravity field (short-arc method) shall require 8 cases for a single iteration -- this will require 2 work days as shown:

<u>Workdays</u>

Data Arc (hrs)	24	24	24	24	1	
Computer Time (hrs)		2	2	2	2	
Data Arc (hrs)	24	24	24	Accumulate Solution		1
Computer Time (hrs)		2	2	2	2	

For 5 iterations, a total of 10 work days is required. This entire process is repeated for the determination of the 30 x 30 gravity field thus requiring an additional 10 work days. Therefore, 20 work days are required to complete the short-arc analysis.

The determination of the 30 x 30 gravity field (long arc method) shall require one work day per iteration (i.e. run submission by 6:00 p.m. and completion by 9:00 a.m. of the following day). Assuming 5 iterations, 5 work days are required although 10 work days have been allocated. This additional time is built into the allocation in order to allow for a) computer operational failures, b) analysis errors which impact computer operations, and c) an alternate analysis methodology which may include the direct modeling of gravity anomalies.

Only if necessary, this last technique shall be repeated using 10 sec (count-time) doppler. One or possibly two iterations will be required; this will require approximately 3 days of computer time.

As outlined, the entire process will require 33 working days. The allocated time for completion of this task is 30 working days plus an additional 4 working days gained from on-going analysis during the data acquisition phase.

4.3.6.11 S,P Kernel Generation and File Transfer

Spacecraft ephemeris files (reconstructed and predicted) will first be generated on the Navigation computer and are known as P-files. For reconstruction, these files will be generated daily; for prediction, they will be generated weekly and will cover a 14-day interval. These files will be transferred, to the Navigation Workstation. The reconstructed P-files will have a well-defined interval of validity (usually 1 day) and will be joined with similarly evaluated P-files resulting in a single file of 7 days duration. Planetary information will be added to this file and the resultant file will be SFDU formatted, transferred to the Project Data Base and thereafter known as the SPK file.

The planetary and satellite ephemeris and partials files are required on the the Navigation computer. Thereafter these files may be updated only 1-2 times throughout the mission (MOSO,L_o).

The SPK file shall be generated in the following amounts of time once the spacecraft, planetary and satellite ephemerides are available. This operation shall be conducted on the Navigation workstation using NAIF supplied software.

	Interplanetary Cruise (331 day file)		Mapping (one day file)	
	SPK File	SFDU Wrapper	SPK File	SFDU Wrapper
Runstream Setup (min)	2	2	2	2
Run Execution Time (min)	5	2	5	2
Printout (min) 5	0	5	0	
Analysis (min)	2	2	2	2

4.3.7 Summary of S/W, H/W and Interface Requirements

This section provides a summarized overview of all files/information required BY the NAS and all files/information required FROM the NAS. Additional abulations show software and adaptions and workstation requirements necessary for the operational NAS environment. These are given in the following five tables.

Table 4.3.1 NAS Major Software Requirements Summary

	PROGRAM	(Responsibility)	Requirement Traceability and Date
1.	DPTRAJ	(Project)	Trajectory - adapt to Mars Global Surveyor mission [L_o, E_o].
2.	ODP	(Project)	Orbit Determination - adapt to Mars Observer mission [L_o, E_o].
3.	Maneuver Operations Program Set (MOPS)	(Project)	Maneuver Planning and Design (MOPS, LAMBO) adapt to MGS mission [L_o, E_o].
4.	UTILITY	(Project)	File manipulation, information display, (NAVINFO) technical calculations (internal to NAS) - adapt to MGS mission [L_o, E_o].
5.	Athena	(MOSO)	Planning tool - update as necessary to meet project studies [As necessary].
6.	FAST	(Project)	Fast trajectory generation for maneuver operations [L_o].
7.	NAIF	(MOSO)	SPK File (S and P kernel generation with appropriate SFDU software) [L_o, E_o].
8.	File Transfer and SFDU Software	(MOSO)	Two-way transfers between Nav Computer, NAV workstations and PDB and SFDU header information
9.	Mars Mapper (retained, not required)		Software retained from MO (spacecraft groundtrack with topography) [$\underline{E}_o$].
10.	Doppler Residual Display On NAV Workstations (DAC)		Monitor doppler residuals for OD and propulsive maneuver assessment [L_o].
11.	Workstation software	(Project, MOSO)	Software for word processor, graphics, and small program execution [With Workstation Delivery].

Table 4.3.2 Required Adaptation of NAVIGATION Operational Software

Launch Delivery (L_o): 3 Nov 95 MO/Galileo Software Inheritance
Encounter Delivery (E_o): Mar-97

	Adaptation (Responsibility)		Delivery Date And Requirement Traceability (Section)
1.	J2000.0 ARS	(Project)	L_o - 4.3.3.1
2.	Non-Gravitational Acceleration Model (Angular Momentum Desaturation)	(Project)	L_o - 4.3.3.1
3.	X-Band Data Computation	(Project)	L_o - 4.3.3.1
4.	X-Band Data Calibrations/ Corrections a) troposphere b) ionosphere c) range corrections d) spacecraft spin correction e) data bias parameters	(Project)	L_o - 4.3.3.1
5.	Software Operational Usage a) user friendly b) interactive c) ease of interpretation	(Project)	L_o,E_o - 4.3.3.1
6.	Gravity Field Model (50x50) (normalized and unnormalized)	(Project)	E_o - 4.3.3.2
7.	Mars Atmospheric Density Model	(Project)	E_o - 4.3.3.1
8	Gravity Anomaly Model (separately and jointly with harmonic model)	(Project)	E_o - 4.3.3.1
9.	Simultaneous Solution of 1000 Parameters	(Project)	E_o - 4.3.3.1
10.	Multiple Data-Arc Merge and Solution	(Project)	E_o - 4.3.3.1
11.	Finite-Burn Propulsive Maneuver with Constant Pitch-Rate	(Project)	L_o,E_o - 4.3.3.3
12.	Accurate Numerical Integration (56 days)	(Project)	E_o - 4.3.3.2
13.	Phobos and Deimos S/C perturbations	(Project)	E_o - 4.3.3.2
14.	Solar Re-radiation from Mars to the Spacecraft	(Project)	E_o - 4.3.3.2
15.	Spacecraft lift perturbation due to atmosphere	(Project)	E_o - 4.3.3.2

Table 4.3.4 Required Input Files/Information to NAS

	Information	(Responsibility)	Traceability (Section)
1.	Planet Ephemeris and Errors and Partial Derivative Files (NAE004)	(MOSO)	4.3.2.1 & MRD
2.	Satellite Ephemeris and Errors and Partial Derivative Files (NAE005)	(MOSO)	4.3.2.1.
3.	Radiometric Data and Related Information		
	a) ATDF(DACE004)	(DSN)	L_o - 4.3.3.1 and MRD
	b) ODF (DACE005), ASTD (DACE047)	(DSN)	L_o - 4.3.3.1 and MRD
	c) Media Calibration Date File (DACE006)	(DSN)	L_o - 4.3.3.1 and MRD
	d) Spacecraft & station time-delay (DACE047)	(DSN)	L_o - 4.3.3.1 and MRD
	f) Time and Polar Motion File (DACE007)	(DSN)	L_o - 4.3.3.1 and MRD
	h) Solar Coronal Model Corrections (memo/algorithm) (NAE015)	(DSN)	E_o - 4.3.3.1
4.	Tracking Station Locations and Errors (DACE009)	(DSN)	L_o - 4.3.3.1 and MRD
5.	Reconstructed Angular Momentum Desaturation (EAS003)	(EAS)	L_o - 4.3.3.1 and MRD
6.	Spacecraft (and Antenna) Spin-rate (EAS006)	(EAS)	L_o - 4.3.3.1
7.	Spacecraft Attitude (HGA and and Solar Panels) (EAS011)	(EAS)	L_o - MRD
8.	Spacecraft mass (throughout mission) (EAS006/EAS014	(EAS)	L_o - MRD
9.	Solar Radiation Pressure Model	(EAS)	L_o - MRD
	a) Spacecraft dimensions	(Memo part of EAS011)	
	b) Specular and diffuse reflectivity coefficients	(Memo part of EAS011)	
10.	Propulsive Maneuver Performance Data File (EAS008)	(EAS)	L_o - 4.3.3.3
11.	Propulsive Maneuver Implementation File (EAS014)	(EAS)	L_o - 4.3.3.3
12.	Doppler Residual Display (from DSN, DACE011,13)	(DSN)	L_o - 4.3.3.1
13.	Range Correction (center-of-phase offset wrt center-of-mass)	(EAS)	L_o - 4.3.3.1 and MRD
14.	Doppler Correction (center-of-phase motion wrt center-of-mass)	(EAS)	L_o - MRD
15.	Launch Polynomials(LUE001) (Injection State Polynomials)	LUE	L_o (Nine months prior to launch) - MRD
16.	Predicted Injection Error Matrix (6x6)	LUE	MRD
17.	Injection Initial Conditions (State Vector)(LUE003)	LUE	L_o - MRD

Note that the utilization and input of these files/information by software-set is given in Section 4.3.5.

Table 4.3.5 Required Products from NAS

	Product/File	Traceability
1.	S and P kernels (SPK File)(NAE011)	
	a) Reconstruction	a) Science data analysis (L_o)
	b) Prediction (14 days)	b) Usage On Spacecraft (L_o)
	c) Prediction (Variable; required at start of sequence planning cycle)	c) Sequence Planning (L_o)
	d) Prediction (56 days)	d) Sequence Planning (E_o),
2.	Orbit Propagation, Timing and Geometry File (OPTG)(NAE003)	Sequence Development (FS)
3.	Light Time File (NAE002)	Sequence Development (FS)
4.	Maneuver Profile File (NAE006) Planning	Propulsive Maneuver (FS)
5.	Astrodynamic Constants and Initial Conditions File(NAE008)	Navigation Astrodynamic Parameters (L_o)
6.	Spacecraft Ephemeris (P-file) (NAE009)	Required for DSN Predictions (L_o)
7.	STATRJ File (NAE001) (Station Polynomial File) Analysis	Required by EAS for Telecommunications (L_o)
8.	Planetary Constants Kernel/File (PcK File) (NAE007)	Auxiliary File Used With SPK file (L_o)
9.	Planet Ephemeris (NAE004)	Required for DSN Predictions (L_o)

4.3.8 Test Requirements

The testing of modifications to existing and certified software shall follow these generalized guidelines:

a) Programmers Code Check

Verify that inputs and outputs to new or modified software are correct and that the code is free from error.

b) Individual Component or Model Check

Verify that the calculations from an individual model or component of the software are correct. Whenever possible compare results with separate and independent software.

c) Overall System Check

Generate test cases similar to those which will be used during flight operations. Verify the proper flow of information within the software and that the calculations and results are correct. This represents an end-to-end or overall system check.

d) Data Flow Check

Verify that all information (or files) flowing between the Project Data Base, the Unisys computer system and the Navigation workstation is timely and free of error. Formatting (and reformatting) of files shall be clearly understood and properly represented.

e) All inputs to programs shall be user-friendly and outputs and displays shall be clear and easily interpretable.

The following are test requirements placed on software modifications to support the mission. Throughout the development phase, other requirements or guidelines may be implemented in order to effectively verify the results of software computations.

4.3.8.1 J2000.0 Astronomical Reference System

The following process is required to test the conversion of the Astronomical Reference System (ARS) to the J2000.0 system:

a) Run existing unit end-to-end test cases and save key files. Refer to these files as the baseline.

b) Write a program to transform the Navigation Constants File (GIN) inputs referred to the B1950.0 ARS to the J2000.0 ARS.

c) Write a program to transform the B1950.0 ARS GIN file inputs to the J2000.0 system using the Newhall technique.

d) Use the B1950.0 DPTRAJ and ODP baseline, J2000.0 Planetary Ephemeris, and modified input from Item 3 to run cases.

e) Use Mars Global Surveyor J2000.0 DPTRAJ and ODP software, J2000.0 Planetary Ephemeris, and input from item 2 to run cases.

f) Compare output for cases run in Items 1 and 5.

g) Compare output for cases run in Items 4 and 5.

4.3.8.2 1000 Solve-For Parameters (Gravity Field Model and Regression Analysis

The following process is required to verify the capability of DPTRAJ to process 1000 solve-for parameters:

a) Execute program PVDRIVE for two cases, each with 60 unique parameters. Spacecraft Ephemeris Files (PV-files) for the two cases shall be created.

b) Execute a run with the combined 120 parameters.

c) Compare the 120 parameter PV-file to the two 60 parameter PV-files.

d) Repeat the above process, increasing the number of parameters, until the desired number of parameters to be utilized is reached.

The following process is required to verify the capability of the ODP to solve for 1000 solve-for parameters:

a) Generate a REGRES File for a 60 parameter case.

b) With a utility program, modify the file to include, for each time tag, 60 more dummy parameters whose partial derivative values are all zero.

c) Generate ODP solutions for the 60 parameter file and the 120 parameter modified file and compare them.

d) Repeat the above process, increasing the number of parameters, until the desired number of parameters to be utilized is reached.

4.3.8.3 Light Time File Modification

To verify the addition of topocentric light times to the Light Time File, light time computations shall be printed from the file generation program LITIME and hand checked.

4.3.8.4 Orbit Propagation and Timing Generation File

The contents of the OPTG File shall be verified by comparing these contents with printout from a TWIST Save File dump.

4.3.8.5 Momentum Reaction Wheel Modeling

Two methods are available for verifying the momentum reaction wheel models. The first method is:

a) Generate a reference trajectory.

b) Generate a trajectory that results from a given position increment at a momentum wheel discontinuity.

c) Compare the two trajectories, which should reveal a difference equal to the input position delta.

The second method is:

c) Generate two impulsive motor burns at approximately the same time. The duration of the burn will achieve an effect which is similar to adding a position increment.

d) Generate a trajectory that results from a given position increment at a momentum wheel discontinuity.

e) Compare the two trajectories.

4.3.8.6 X-Band Uplink Radiometric Data Processing

To verify X-band computations in the software print out charged particle and tropospheric computations for each leg of the X/X (X uplink/X downlink) radiometric data. Compare results with hand computations.

4.3.8.7 Mars Atmosphere Density Model

Compare atmospheric density profiles resulting from the ODP with an independent coding of the same model which currently exists. Verify accurate evaluation of data partial derivatives for drag parameters. Determine computer execution times for atmospheric drag calculations over many orbits (typically 100-200 orbits).

4.3.8.8 Spacecraft-HGA-Motion Calibration Model

Compare doppler corrections due to HGA motion from navigation operational software with a "stand-alone" or independent coding of this software.

Verify that the spacecraft's attitude is correct and that the latest parameters and information relating to spin and offset (center-of-mass to HGA center-of-phase) have been utilized. Provide for the capability to update these as necessary.

4.3.8.9 Many-Orbit Integrations: Numerical Accuracy

Determine accuracy of orbital variables associated with numerical integrations of hundreds (nominally 200 but as many as 700) of orbits.

4.3.9 Traceability of Navigation Requirements

All requirements identified in the NAS design are traceable to higher level requirements and documents or are derived from these. These documents include:

a) Mission Requirements Document

b) Investigation Description and Science Requirements Document

c) Spacecraft Requirements Document

d) Mission Plan

e) Planetary Constants and Models

f) MOS Specification Documents.

4.4 ENGINEERING ANALYSIS SUBSYSTEM

The Engineering Analysis Subsystem (EAS) consists of the hardware and software tools which the Spacecraft Team uses to operate and maintain the Mars Global Surveyor (MGS) Spacecraft System and Subsystems in support of achieving Mission Operations.

4.4.1 INTRODUCTION

This section is one in a series which describe the functional requirements on the MGS Ground Data System. Section 4.4.2 defines the scope of the EAS and this document. Section 4.4.3 gives an overall conceptual design including interfaces with other portions of the GDS. Section 4.4.4 summarizes the computer hardware environment necessary for performance of EAS functions. Section 4.4.5 details the software functional requirements for each component of the EAS. Section 4.4.6 describes the external interfaces between the EAS and other GDS components, including estimated data volumes and frequencies. Section 4.4.7 contains a trace matrix of Level 4 EAS requirements to Level 3 GDS MOS Requirements contained in Section 3.4.9 of this document. Section 4.4.8 describes the EAS Test requirements.

4.4.2 SCOPE

The Engineering Analysis Subsystem includes the Engineering Analysis Workstations and the Spacecraft Performance Analysis Software (SPAS) that executes therein. This document decomposes the EAS into eight functional areas, corresponding to systems and the major spacecraft subsystems. For each area, the basic set of computer hardware necessary and a definition of required software functions are given. This document also contains definitions of software functions not designated to a particular subsystem, including Data Processing, utility and file transfer programs.

4.4.3 CONCEPTUAL DESIGN

In order to perform the functions necessary to process spacecraft engineering data to analyze and maintain the health and performance of spacecraft subsystems, two GDS subsystems are invoked sequentially. The first is the Data Acquisition and Command Subsystem and the second is the Engineering Analysis Subsystem, the subject of this document.

The software and hardware to perform the real-time telemetry processing function will be provided by the Multimission Operations Support Office (MOSO) at JPL and implemented by the Multimission Ground Data System (MGDS). (This section assumes the MGDS and Advanced Multi-Mission Operations System [AMMOS] configuration is as presently defined.). The SCT interface to this system will be through the Project Data Base (PDB).

The configuration for Flight Operations Ground Data System is illustrated in Figure 3.4. It consists of Local Area Networks (LAN) at both the SCT MSA at JPL and at Denver. The Denver LAN is supplied with data via a 448k bps dedicated digital line from JPL. Spacecraft telemetry is available from the Project Data Base of the AMMOS to either LAN. Telemetry workstations are shown at JPL and Denver for spacecraft subsystems real-time telemetry processing. Each of the telemetry workstations will access the S/C real-time telemetry stream via the LAN and extract their portion of the telemetry. These workstations will also host the MOS Analysis and Prediction software used by the Spacecraft Team. This software is collectively called the Spacecraft Performance Analysis Software (SPAS).

The software and hardware to perform the analysis functions constitute the EAS. These consist of SUN workstations (called Engineering Analysis Workstations) and associated peripheral equipment resident in the SCT MSA in Denver. These Engineering Analysis Workstations are designated for Propulsion/Mechanics, Power, Thermal, AACS, C&DH, Telecomm, Flight S/W Mgmt, and Systems. Data handling and processing software to manage file transfers between machines and databases along with utility programs complete the software set. Table 4.4.3-1 summarizes the required software and gives its inheritance and status.

Table 4.4.3-1 EAS Mission Operations Software

Subsystem	Software	Function	Provided By	Status
Propulsion/ Mechanics	MASSPROP	Center of Mass & Inertia	MO/MGS SPAS	Inherited/Modified
	IDEAS/Models	Graphic S/C Visualization	Commercial S/W	Commercial S/W
	Prop_Perf	Propulsion Performance Analysis	MO PAS/MGN	Inherited/Modified
Power	SOLAR	Determine/Predict Health & Perf of SA	MO PAS	Inherited
	LOAD/POWER	Power Consumption	MO PAS/MGN	Inherited/Modified
	ENERGY_BAL	Energy Balance	MO PAS/MGN	Inherited/Modified
Thermal	TRASYS & SINDA	Thermal Analysis	MO/MGN	Inherited
AACS	MOMENTUM	Analyze Momentum Unloading	MO PAS/MGN	Inherited/Modified
	STAR	Star Selection Generation	MO PAS	Inherited
	TRANS	Planetary & S/C Ephemeride	MO PAS	Inherited
	MAN_DES	Maneuver Design	MO PAS	Inherited
	ATTREC	Attitude Reconstruction	MO	Inherited
C&DH	MEM_TRK	Track On-Board S/C Data (SSR)	MGS SPAS	New Development
	CV_MON	Upload Command Verification	MO/MGS SCT	Inherited
Telecomm	TPAS	Uplink & Downlink Perf Assess	JPL	Inherited
	Excel	Predictive Telecomm Capability	MO/MGN	Inherited/Modified
Flight Software	MST	Memory State Tracker	MGS SPAS	New Development
	FSW Tools	Flight Software Dev Tools	MO	Inherited
	PARM_TRK	Parameter Tracking	MGS SPAS S/W	New Development
	PDS_Tools	Track Cmds to Science Instr/PDS Analysis & FLT S/W Maintenance	MO PDS GSW	Inherited
Systems	tbd			
DP and Utility S/W	VMPLOT	General Plotting Tool	MGN	Inherited
	TDE	Telemetry Dictionary (Decom/Decal)	MGS SPAS	New Development

There are two primary types of activities to be performed; 1) Telemetry Analysis and 2) Subsystems Performance Prediction. A prediction run can be initiated either to generate parameters to be uploaded to the spacecraft (e.g., engine burn times for a TCM) or to generate a predict file to be used to compare against telemetry (e.g., predicted power profile). The telemetry analysis run will access a telemetry file from the PDB and may compare measurement against predicts, perform trend analysis, evaluate subsystem performance, or compute parameters to be uploaded to the spacecraft (e.g., gyro biases).

A summary of spacecraft (S/C) subsystems analysis and prediction activities is given in Table 4.4.3-2 for each of the Engineering Analysis Workstations. Detailed software requirements for performing these activities are given in Section 4.4.5.

Table 4.4.3-2 S/C Subsystems Analysis Activities

PROPULSION/MECHANICS

- Compute S/C Center of Mass and Inertia
- Provide Graphic S/C Visualization
- Generate Status And Performance Data For Propulsion Subsystem
- Support Maneuver Design And Reconstruction By Nav Team
- Compute Engine Burn Times

POWER

- Generate Status Of EPS, Solar Arrays, And Batteries
- Determine S/C Energy Balance (Amp-Hrs In/Amp-Hrs Out) And Battery DOD
- Generate Predicted Power Profile From Planned Sequence
- Compare Actual Power Profile With Predicted

THERMAL

- Generate Thermal Data For Status Of S/C
- Analyze Performance Of Thermal Subsystem
- Generate Predicted Temperature Profiles From Planned Sequences
- Compare Actual Temperatures With Predicts

AACS

- Generate Status Data For AACS Subsystem
- Analyze Attitude Control Performance
- Calibrate Gyros: Compute Upload Parameters
- Determine S/C In-Flight Inertias About Axes
- Compute Polynomial Coefficients For Upload To Determine:
    - Cruise Attitude Quaternions
    - Earth Pointing Attitude Quaternions
    - Sun Vector
- Maintain AACS Rom Safing Data In C&DH Memory
- Compute Maneuver Preparation Data For Upload
- Generate Star Scan Data For Upload
- Attitude Reconstruction For HGA Calibration
- Support Maneuver Design And Reconstruction By Nav Team
- Generate Attitude Profiles

Table 4.4.3-2 S/C Subsystems Analysis Activities (Cont.)

C&DH

- Perform Tracking of On-Board S/C SSR Data
- Perform Upload Command Verification
- Analyze C&DH Performance

TELECOMMUNICATIONS

- Generate Status Data For Telecomm Subsystem
- Analyze HGA Boresight Calibration
- Perform Telecom Link Predictions
- Analyze Actual Telecom Link Performance

Flight Software

- Perform Flight Memory Analysis and Compare
- Maintain Flight Software
- Track Commands to the PDS and Science Instruments
- Perform Parameter Tracking

SYSTEMS

- tbd

4.4.4 HARDWARE ENVIRONMENT

This section contains the computer hardware requirements for each Engineering Analysis Workstation of the Engineering Analysis Subsystem. Interfaces between the Engineering Analysis Workstation computers and the rest of the GDS are illustrated in Figure 3.4.

4.4.4.1 Engineering Analysis Workstations

The major hardware component of the EAS is the workstation. All EAS workstations shall be nodes on the MGS local area net of the MGDS multimission system. All EAS workstations shall be connected to the Project Data Base (PDB) for purposes of data transfer.

1. The requirements for the Engineering Analysis Workstations (EAWS) are as follows:

   b) Any workstation assigned to the EAS shall be capable of running all of the application software listed in the application software section 4.4.5.
   c) Every EAS workstation shall be capable of displaying the results of multi-colored plotting routines, multi-colored alarm display routines, and colored graphics in explanatory analysis reports.
   d) The workstations shall be configured such that any EAS analyst with appropriate authority shall be able to run any EAS program from any EAS workstation.
   e) The Engineering Analysis Workstations shall consist of SUN Sparc 2 (or better) workstations and associated peripherals.
   f) The minimum software for all EAWS include SunOS 4.1.3, Motif 1.1.2, and AMMOS V19.n.

2. Workstation Quantities:
   Current estimates of workstations for use in the SCT MSA in Denver are shown graphically in Figure 3.4 and listed in Table 3.1.

3. Peripherals:

   d) The minimum peripherals for each EAWS include One 1/4" Cartridge Tape Drive
   e) One CD-ROM Reader
   f) Necessary hardware for network connectivity
   g) Color monitor
   h) One Sparc Printer for each operational subsystem (8)
   i) Optical Storage Disk System
      - An optical storage disk system shall be available to any EAS analyst for on-line archiving of data. The disk component shall be a multi-function 5-1/4 inch removable assembly. This optical storage system shall be usable for both WORM (Write Once Read Many) and Erasable Magneto-Optic type media. Analysts from the EAS disciplines may store data in a manner suitable for their use in carrying out their duties. Storage capacity of 654 MB to 1GB shall be available for analyst usage. At least eight (8) units of these optical disk systems shall be available for the EAS.

4.4.5 OPERATIONS SOFTWARE FUNCTIONAL REQUIREMENTS

The SCT MOS software contained in the EAS is involved in both evaluation of past spacecraft performance and prediction of future performance. This results in two subcategories of software to accomplish the task. The first is Telemetry Analysis software which will access files of data which have been decommutated, decalibrated, converted and sorted into measurement types by the Data Acquisition and Command Subsystem. These programs will further process and reduce the telemetry to permit quantitative evaluation of subsystem performance.

The second group of programs are those that predict subsystem performance or spacecraft state based on extrapolation of current conditions or upon planned uplink changes. These programs may be executed several times prior to a given upload to permit evaluation of upload options and selection of the optimum course of action. Many of these programs also generate parameter values to be uploaded to flight memory to maintain accurate performance of the spacecraft or subsystem.

Analysis and prediction software will be available during mission operations for the following Spacecraft Team areas: Propulsion/Mechanics, Power, Thermal, AACS, C&DH, Telecommunications, Flight Software, and Systems.

The software used by the SCT as part of the EAS will be collectively called the Spacecraft Performance and Analysis Software(SPAS).

Requirements for these functions are described in the following sections.

4.4.5.1 Propulsion/Mechanics Subsystem

4.4.5.1.1 S/C Mass Properties Determination (MASSPROP)

4.4.5.1.1.1 Functional Description

During the course of the mission, the spacecraft team and other teams supporting the mission will need to know the center of mass and the inertia dyadic of the spacecraft. The center of mass will be needed for maneuver planning to ensure that thrust vectors are directed through the center of mass of the spacecraft and the inertia dyadic will be needed for spacecraft rotational momentum analysis (i.e. PAS application MOMENTUM).

The PAS Mass Properties function (MASSPROP) will enable a spacecraft team analyst to calculate the center of mass and the inertia dyadic using information about the mass, shape, and location of the components and subassemblies that make up the spacecraft, calculated values of the fuel remaining in the tanks, and the deployment positions of spacecraft equipment relative to the mission phase. The algorithms and equations required for this application will be modeled after a program, named Mass Properties, developed and used by GE ASD engineers as a design tool for the structural design of a spacecraft.

4.4.5.1.1.2 Input Requirements

(1) Non-telemetry data that consists of the following:

The program requires an input file that lists all of the components or subassemblies (up to 1000 items) that make up the spacecraft and their position on the spacecraft. The input file has a hierarchical structure that relates parts to higher assemblies and regions of the spacecraft.

The program will require the following information in the input file in order to compute the center of mass.

- A listing of all of the parts that make up the spacecraft. This includes systems, assemblies, subassemblies, and parts.
- The hierarchical relationship of all the parts to subassemblies, assemblies, and systems. Special coded part numbers in the input file are used to code this information.

- The weight of each part.

- The center of mass and dimensional information for each part. Used to calculate the inertia.

- The physical location of each part on the spacecraft. This is broken down into regions and zones of the spacecraft body.

- The mass remaining in the propellant tanks for the time when the center of mass calculation is desired. This information will be obtained using output from the TANKS program, output from the MASSLOSS program, or any combination of the two.

- The status of all of the deployable elements in the Mechanical subsystem of the spacecraft as a function of mission phase/time since launch.

(2) Operator input specifying the following:

- File names
- Operational flags
- Deployment positions

4.4.5.1.1.3 Processing Requirements

The mass properties function shall perform the following:

(1) Link the weight data and the inertial data together for each part of the spacecraft using data from the input file.

(2) Calculate the inertia for each part using the information about the shape and orientation of each part. This is done by modeling each part as the simple geometric solid that most closely approximates it. The input file data contains the information on which geometric model to use. Subroutines are used for the various shapes, such as a solid cylinder, hollow cylinder, thin-walled tube, hemispherical shell, thick-walled hemispherical shell, right angle wedge, solid hemisphere, and truncated thin-walled cone.

(3) Calculate the rotations necessary to correctly orient the part on the spacecraft.

(4) Integrate the inertia, weight, and spatial arrangement data by region of the spacecraft body and then for the whole spacecraft to determine the center of mass and the inertial matrix of the spacecraft.

4.4.5.1.1.4 Output Requirements

The output shall consist of a file that contains:

(1) The spacecraft's total mass

(2) The position of the center of mass of the spacecraft in spacecraft x, y, z coordinates.

(3) The 3x3 moment of inertia matrix for the spacecraft.

4.4.5.1.2 Fuel Level Determination (TANKS)

4.4.5.1.2.1 Functional Description

The TANKS program is provided as a backup tool for the propulsion analyst to determine the amount of expendables remaining in the monopropellant and bipropellant tanks at any point in the mission. The primary means of fuel-level determination is through the Guidance and Control Subsystem maneuver planning and reconstruction programs using thruster flow rates. TANKS approaches the determination problem via ideal gas law theory applied to tank temperature and pressure telemetry.

Knowledge of the tank-by-tank fuel remaining primarily affects maneuver planning, but also contributes to understanding and predicting spacecraft dynamics through the small resulting displacements of the center of gravity as fuel is consumed. The primary use of the TANKS program is anticipated to be in gauging fuel level just before and just after a maneuver to serve as a partial check on the maneuver program's flow-rate fuel consumption calculation. The check is only partial since the ideal gas law method is considered inherently less accurate then the flow-rate method.

During the intervals between maneuvers, fuel is only used for minor attitude corrections and consumption is minimal. Monitoring fuel quantities during these intervals provides a coarse check on the integrity of the propulsion subsystem.

The TANKS program shall also provide the maneuver planning software with the following:

(1) Average tank pressures used to calculate thrust and Isp in the monopropellant blowdown mode.

(2) Mass ratios in the monopropellant tanks to distribute the single mass loss calculated using thruster flowrates among the 2 hydrazine tanks.

(3) Mass ratios in the bipropellant tanks to distribute the single mass loss calculated using thruster flowrates among the MMH and NTO tanks.

The TANKS program calculates fuel weight in each tank of the monopropellant and bipropellant systems using tank average temperature and pressure. All sensors for the tank and all telemetry points over the interval are factored into the tank average. The fundamental assumption of the TANKS program is that temperature and pressure averaging is performed under conditions of thermal equilibrium and constant pressure.

4.4.5.1.2.2 Input Requirements

Fuel level determination requires as input:

(1) S/C telemetry that describe tank temperature and pressure as a function of time.

(2) Static s/c data that describe:

- Tank volume, tank initial ullage pressure, and tank initial mass.
- Physical constants (e.g. hydrazine density and the ideal gas law constant).

(3) Operator input specifying the following:

- File names.
- Operational flags.
- Time interval and sampling frequency for the required telemetry points for subsequent processing of retrieved telemetry file. Telemetry file retrieval is assumed to have already occurred.

4.4.5.1.2.3 Processing Requirements

The monopropellant and bipropellant fuel remaining calculations are treated separately as follows:

The monopropellant calculation determines the mass remaining in each of two hydrazine tanks from tank pressure and thermal sensor telemetry and involves four primary steps:

(1) Average monopropellant system tank temperatures.

(2) Calculate initial ullage volume.

(3) Calculate initial blowdown pressure.

(4) Determine hydrazine mass remaining.

The bipropellant calculation determines the mass remaining in the NTO oxidizer tank and MMH fuel tank from tank pressure and thermal sensor telemetry. The calculation requires two primary steps:

(1) Average bipropellant system tank temperatures.

(2) Determine the fuel and oxidizer mass remaining.

4.4.5.1.2.4 Output Requirements

The output shall consist of a file that contains the amount of fuel remaining at a specified time in:

(1) Pair of hydrazine fuel tanks.

(2) MMH fuel tank.

(3) NTO oxidizer tank.

(4) Averaged temperature and pressure values for each tank.

4.4.5.1.3 Propulsion Analysis Software (PROP_PERF)

4.4.5.1.3.1 Functional Description

The PROP_PERF software is designed to compute engine burn duration for upcoming delta-V maneuvers (e.g., TCM or OTM) and for post maneuver reconstruction.

4.4.5.1.3.2 Input Requirements

(1) S/C event time of burn, and required Spacecraft delta-V from the Navigation Team.
(2) Propulsion subsystem temperature predicts, and other critical subsystem temperature predicts from the Thermal unit.
(3) Propulsion subsystem state parameters (e.g., engine and valve configuration, current tank pressure, etc).

4.4.5.1.3.3 Processing Requirements

(1) PROP_PERF shall model the actual MGS propulsion subsystem in characteristics and number of components such as:
   - Propellant and Pressurant Tanks
   - Valves, Filters and Lines
   - Pressure-Fed Engines and Thrusters
   - Liquid Hydrazine Propellant

(2) PROP_PERF shall incorporate heat transfer, mass transfer, flow rate, and pressure drop equations to model the expected conditions of the MGS mission.

(3) PROP_PERF input shall include the required delta spacecraft velocity and spacecraft event time of the start of the maneuver, all provided by the Navigation Team.

(4) PROP_PERF input shall include propulsion subsystem temperature predicts from the Thermal Unit of the Spacecraft Team.

(5) Propulsion subsystem state parameters, such as the engine/valve/line configuration, shall be specified for PROP_PERF input along with any initial conditions for parameters, such as tank pressures, which are obtained from telemetry printout.

(6) PROP_PERF shall compute the required burn duration and time profiles of thrust and mass expended, based on predicted performance and required delta velocity.

(7) PROP_PERF output shall be stored in a file which can then be displayed to the CRT and/or printed. The output will be computed burn duration needed and predicted values of propulsion subsystem parameters such as temperatures, pressures and flow rates.

4.4.5.1.3.4 Output Requirements

The output shall consist of a file containing:

(1) Burn duration
(2) Predicted temperatures and pressures.
(3) Flow rates, engine performance.

4.4.5.2 Power (PWR) Subsystem

4.4.5.2.1 Solar Array Performance (SOLAR)

4.4.5.2.1.1 Functional Description

The solar array is the sole source of electrical power for the spacecraft. The ability to analyze its performance and general health is valuable to the spacecraft team for determining the current state of the solar array and also for the planning of spacecraft activities and the power loads that the activities would require.

The SPAS Solar Array Performance function (SOLAR) will enable a spacecraft team analyst to determine the present effects of solar radiation on the solar array. This will be accomplished by using spacecraft telemetry from the PDB, reference data from static reference files, and operator input from the analyst. The data will be used by the SOLAR application to determine an estimate of the effect of solar radiation degradation on the array.

The program generates solar array performance information which can be compared to expected radiation degradation characteristics or trended over time to give the spacecraft team analyst an insight into how aging and the environment are affecting the solar array.

4.4.5.2.1.2 Input Requirements

Calculation of the solar array cell degradation due to radiation effects shall require as input:

(1) S/C telemetry data that indicate:

- Solar cell short circuit current representative of the solar array
- Solar cell open circuit voltage representative of the solar array
- Solar array temperature
- Inertial to s/c body quaternion
- Solar array normal vector

(2) Static data that indicate:

- Functional dependence of sun incidence angle versus spacecraft/sun angle.
- Functional dependence of relative current factor versus sun incidence angle.
- Functional dependence of solar constant correction factor versus time from launch.

- Functional dependence of temperature correction factor versus time from launch indicating the effect of temperature degradation on solar array output.
- Initial solar cell short circuit current taken as first reading after launch to be used as a baseline for future comparison.

(3) Operator input specifying:

- Time interval and sampling frequency for the required telemetry points for subsequent processing of retrieved telemetry file. Telemetry file retrieval is assumed to have already occurred.
- Time from launch for extracting information from functionally dependent variables.

4.4.5.2.1.3 Processing Requirements

Calculation of the solar array cell degradation involves the following:

(1) Determine the s/c's orientation to the sun.

(2) Determination of the solar constant correction factor given a specific time.

(3) Determination of the sun incidence angle.

(4) Determination of the relative current factor given the sun incidence angle.

(5) Determination of the temperature correction factor.

(6) Correct the solar cell short circuit current for solar constant, relative current, and temperature affects at specified time.

(7) Calculate the solar cell degradation factor by comparing corrected solar cell short circuit current to the baseline current.

4.4.5.2.1.4 Output Requirements

The output shall consist of a file that contains:

(1) Corrected initial solar cell short circuit current.

(2) Corrected solar cell short circuit current.

(3) Solar cell degradation factor.

4.4.5.2.2 Load Performance (LOAD)

4.4.5.2.2.1 Functional Description

How the available electrical power is utilized by the various spacecraft loads is required for the management of the spacecraft's power resources. The spacecraft team power subsystem analyst would work with the sequencing team to command any required changes in the loading due to abnormal power demands from equipment, with the spacecraft team thermal subsystem specialist regarding heater loads, and with the science team regarding unexpected instrument behavior that analysis may reveal.

The SPAS Load Performance function (LOAD) will enable a spacecraft team analyst to examine the distribution of electrical current throughout the spacecraft to determine power subsystem distribution performance. The application will accomplish this by analyzing the power usage requirements of all spacecraft components compared to the expected load profile, and by analyzing the distribution of available electrical current within the power subsystem.

The outcome from the use of this application is load performance information which can be compared to expected performance characteristics or trended over time to give the spacecraft team power subsystem analyst an insight into how the electrical power loads are behaving and how effectively they are being managed.

4.4.5.2.2.2 Input Requirements

Load verification shall require as input:

(1) S/C telemetry data that indicate:

- Current load profile (e.g. operational status of each piece of equipment).
- Battery 1 discharge current.
- Battery 2 discharge current.
- Battery 1 charge current.
- Battery 2 charge current.
- Regulated bus current.
- Regulated bus voltage.
- Battery 1 voltage.
- Battery 2 voltage.
- Solar array current.

(2) Static data that indicate:

- Current requirements for each piece of equipment.

(3) Operator input specifying.

- Time interval and sampling frequency for the required telemetry points for subsequent processing of retrieved telemetry file. Telemetry file retrieval is assumed to have already occurred.

4.4.5.2.2.3 Processing Requirements

Load performance shall involve the following:

(1) Calculate the BVR transfer efficiency.

(2) Examination of system performance shall involve the following:

If the solar array is illuminated and the s/c load currents are less than the solar array current (i.e. batteries charging) then:

(A) Calculate a solar array current to compare to the measured current by summing:

- Regulated bus current.
- Battery 1 charge current.
- Battery 2 charge current.
- Current loss in PSE.

If the solar array is illuminated and the s/c load currents are greater than the solar array current (i.e. batteries discharging) then:

(B) Calculate a regulated bus current and compare to the measured current using:

- Battery 1 discharge current.
- Battery 2 discharge current.
- Battery 1 voltage.
- Battery 2 voltage.
- BVR transfer efficiency.
- Regulated bus voltage.
- Solar array current.

(3) Compare the expected load profile with the regulated bus current.

4.4.5.2.2.4 Output Requirements

The output shall consist of a file that contains:

(1) BVR transfer efficiency.

(2) Expected and measured bus current.

(3) Expected and measured solar array current.

4.4.5.2.3 Power Energy Balance (EB5D3)

4.4.5.2.3.1 Functional Description

The power energy balance (EB5D3) program is GE heritage software that shall be modified to accommodate the UNIX operating system. The program determines the current and predicted energy balance of the s/c. The energy balance provides solar cell performance (e.g. voltage versus current characteristics), battery performance during eclipse, and battery, solar array, and electrical box performance over time (e.g. throughout each orbit).

4.4.5.2.3.2 Input Requirements

(1) The program requires an input file that contains information in the following areas:

- Program parameters (e.g. time integration step).
- Orbit parameters (e.g. total orbit duration, eclipse duration).
- Battery parameters (e.g. battery cell and total capacity, battery trickle charge, battery voltage vs. current characteristics).
- Solar array parameters (e.g. solar cell reference temperature, solar cell voltage vs. current characteristics).
- Load/System parameters (e.g. system load voltage, BVR efficiency).

(2) Operator input specifying:

- File names.
- Operational flags.

4.4.5.2.3.3 Processing Requirements

All calculations required to perform a s/c power energy balance are contained in the EB5D3 model.

4.4.5.2.3.4 Output Requirements

The output shall consist of a file that contains:

(1) Solar cell voltage vs. current characteristics of the degraded solar cell.

(2) For each orbit:

- Summary of battery discharge cycle (eclipse) performance.
- Battery state of charge.
- Charge to Discharge ratio.
- Battery current and voltage.
- Battery bus voltage.
- Voltage at the BCA.
- Solar array available current.
- Solar array current used.
- Operating voltage.
- Power used.
- Regulated bus load current and power.
- Battery, PSE, and BCA heat dissipation.
- End of orbit battery summary.

4.4.5.2.4 Solar Array Synthesis Program (SASP)

4.4.5.2.4.1 Functional Description

The Solar Array Synthesis (SASP) program is GE heritage software (Ref: PWR SYS-82-196 User's Guide to Computer Program SASP) that shall be modified to accommodate the UNIX operating system. The program calculates solar array cell voltage (I-V) characteristics and produces a family of I-V curves over the range of solar array operating temperatures. The program accounts for solar cell arrangement (e.g. series or parallel), solar cell degradation due to charged particle irradiation, and solar array temperature and sun incidence angle profiles.

4.4.5.2.4.2 Input Requirements

(1) The program requires an input file that contains information in the following areas:

- Program parameters (e.g. time integration steps).
- Orbit parameters (e.g. total orbit duration, eclipse duration).
- Solar array parameters (e.g. solar cell short circuit current and voltage temperature coefficients, solar cell degradation factor).

(2) Operator input specifying:

- File names.
- Operational flags.

4.4.5.2.4.3 Processing Requirements

All calculations required to produce solar cell I-V curves are contained in the SASP program.

4.4.5.2.4.4 Output Requirements

The output shall consist of a file that contains:

(1) Solar array cell I-V curves.

(2) Open short circuit current, maximum power point current and voltage, and open short circuit voltage for input cell I-V curve.

(3) Solar array voltage.

(4) Total solar array current and power at each voltage for each time step.

4.4.5.2.5 Partial Shunt Regulator Program (PSRP)

4.4.5.2.5.1 Functional Description

The Partial Shunt Regulator (PSRP) program is GE heritage software (Ref: ES-TCH-0517). Partial Shunt Regulator (AC/DC) Program) that shall be modified to accommodate the UNIX operating system. The program determines the load characteristics for a solar array utilizing partial shunts.

4.4.5.2.5.2 Input Requirements

(1) The program requires an input file that contains information in the following areas:

- Solar cell I-V curves.
- System Parameters (e.g. degradation factors, temperature coefficients, beginning and incremental shunt currents)
- AC Load values for each circuit.
- Shunt/Bus Parameters (e.g. regulated bus line resistance and voltage loss, shunt line resistance and voltage loss, relative and absolute shunt sharing values).
- Solar Array Circuit Parameters (e.g. upper and lower solar array characteristics, solar array temperature and incidence angle)

(2) Operator input specifying:

- File names.
- Operational flags.

4.4.5.2.5.3 Processing Requirements

All calculations required to produce load characteristics for solar arrays utilizing partial shunts are contained in the PSRP program.

4.4.5.2.5.4 Output Requirements

The output shall consist of a file that contains:

(1) Current-voltage-power characteristics for each shunt circuit.

(2) Current-voltage-power characteristics for shunt circuit sharing.

(3) Shunt profiles of current, voltage, and power.

4.4.5.3 Thermal Subsystem

4.4.5.3.1 Thermal Radiation Prediction Software (TRASYS)

4.4.5.3.1.1 Functional Description

To generate predicts of thermal radiation data for the MGS spacecraft under specific mission conditions.

4.4.5.3.1.2 Input Requirements

(1) Data file containing S/C thermal characteristics (manually generated).
(2) NAV orbital data (manual input to data file).
(3) Planned and actual S/C attitude and configuration (manual input to data file).
(4) Run control parameters. (interactive)

4.4.5.3.1.3 Processing Requirements

(1) This program shall be a MGS-specific version of the standard thermal program TRASYS (Thermal Radiation Analysis System) currently being used to design the MGS Thermal Control Subsystem.

(2) TRASYS shall accept a file of MGS spacecraft thermal characteristics as input. This file shall be built and maintained by the thermal engineer.

(3) TRASYS shall accept data derived from AACS supplied spacecraft attitude or configuration timeline information as input. This will be a manual input.

(4) TRASYS shall accept as input the sun beta and sigma angle from the NAV supplied OPTG file. This will be a manual input.

(5) TRASYS shall compute the thermal radiation environment of the spacecraft considering spacecraft characteristics, orientation with respect to the sun, and position in orbit. It shall model the actual MGS thermal subsystem and geometry to predict the thermal radiation environment for all expected MGS mission conditions.

(6) TRASYS shall output a file of thermal radiation data to be input to SINDA, and shall be capable of routing this output to a printer.

4.4.5.3.1.4 Output Requirements

The output shall consist of a file that contains:

(1) thermal radiation output data.

4.4.5.3.2 Temperature Predictions (SINDA)

4.4.5.3.2.1 Functional Description

To generate predicted S/C subsystem temperatures versus time to assist sequence planning and to compare with actual telemetry values to evaluate subsystem performance.

4.4.5.3.2.2 Input Requirements

(1) Thermal radiation output file from TRASYS.
(2) Run control parameters. (Interactive)

4.4.5.3.2.3 Processing Requirements

(1) This program shall be a MGS-specific version of the standard thermal analysis program SINDA '85, (Systems Improved Numerical Differencing Analyzer) currently being used to design the MGS thermal control subsystem.

(2) SINDA shall accept the thermal radiation output file produced by TRASYS as input.

(3) SINDA users shall access a printout from the Planning and Sequence Subsystem. This printout will contain a sequence of spacecraft component On-Off times (with the exception of heater power usage). Information derived from the printout shall be a manual input.

(4) SINDA shall compute the thermal conduction and radiation interchange of the spacecraft as a function of time. It shall model the actual MGS subsystems to predict temperature versus time at specified nodes under all possible MGS mission conditions. Selected expected conditions will be pre-run, prior to launch.

(5) SINDA shall output to a printer a list of predicted temperatures versus time for requested temperature measurements.

(6) SINDA shall output a plot file of temperature versus time histories for specified thermal nodes. This plot file will be used by the VMPLOT utility for overplot with engineering telemetry.

(7) SINDA shall output a file containing S/C heater load versus time and battery and solar array temperatures versus time.

4.4.5.3.2.4 Output Requirements

The output shall consist of a file that contains:

(1) File of predicted temperatures versus time for requested nodes.
(2) File of predicted temperatures versus time (VMPLOT file).
(3) File of predicted heater load and battery and solar array temperatures versus time.

4.4.5.4 Attitude and Articulation Control Subsystem (AACS)

4.4.5.4.1 S/C Momentum Prediction (MOMENTUM)

4.4.5.4.1.1 Functional Description

The control of the buildup and unloading of the spacecraft's angular momentum is critical for the accurate pointing of a 3-axis stabilized spacecraft like the Mars Observer. Various sources such as aerodynamic drag and the pressure of sunlight on the solar array add angular momentum to the spacecraft that, if it were not countered by the spacecraft's attitude control equipment, would cause the spacecraft to rotate in an uncontrolled manner. The ability to analyze the buildup and unloading of momentum and to make predictions as to the near-future momentum controlling would be valuable to an analyst for determining the performance and health of the spacecraft attitude control system and in studying unusual or anomalous spacecraft attitude behavior, and in some cases to intentionally schedule unloading sessions to avoid critical science acquisition periods.

The SPAS S/C Momentum Prediction function (MOMENTUM) will enable a spacecraft team analyst to take telemetry data on spacecraft rotational momentum and body rotation rates and generate a predictive equation that can predict near-future momentum buildup and can be used to determine approximate unloading times. The equation can also be used to analyze the buildup of angular momentum on the spacecraft in the study of anomalous spacecraft attitude behavior.

The outcome from the use of this application is a predicted rotational momentum profile and a prediction equation. This information could be used by an analyst for determining the performance and health of the spacecraft attitude control system or in the investigation of unusual spacecraft attitude behavior.

4.4.5.4.1.2 Input Requirements

The S/C momentum calculation and prediction of future momentum unloading events requires as input:

(1) S/C telemetry which consist of time tagged:

- S/C filtered body rates.
- System momentum vector.

(2) Static s/c data which consist of:

- S/C momentum unloading thresholds for each of the four RWAs.

(3) Operator input specifying:

- Time interval and sampling frequency for the required telemetry points for subsequent processing of retrieved telemetry file. Telemetry file retrieval is assumed to have already occurred.
- Mission date and time at which the momentum analysis is conducted.

4.4.5.4.1.3 Processing Requirements

The processing functions required to calculate and predict s/c momentum include:

(1) Generation of a set of coefficients that describe the curves representing s/c momentum along each axis over time.

(2) Extrapolation of future momentum values, using the derived set of coefficients, compared to unloading thresholds to predict when a series of momentum unloading events should occur.

(3) The extrapolation of momentum should account for momentum reset after each unloading event.

4.4.5.4.1.4 Output Requirements

The output shall consist of a file that contains:

(1) Extrapolated angular momentum vectors and a time tag for each vector for each axis.

(2) The time of predicted momentum unloading events.

(3) The prediction equation coefficients for each axis.

4.4.5.4.2 Star Catalog Generation (STAR)

4.4.5.4.2.1 Functional Description

In order for the celestial sensor assembly (CSA) to function properly as part of the spacecraft's attitude control system, the spacecraft requires periodic updates to its star catalog to account for the s/c's motion. These updates contain star catalog information identifying each star's location and associated silicon magnitude in the CSA's field of view. In addition, the position of the Earth, Mars, and other planets in the field of view, and the motions and perturbations of these planets against the sky need to be correctly accounted for. Lastly, the star catalog must be transformed into the proper reference frame and coordinate system required by the s/c.

The SPAS Star Catalog Generation function (STAR) will enable a spacecraft team analyst to generate a star catalog for uplink to the spacecraft for use by the spacecraft's CSA and A&ACS. The application will accomplish this by sorting through source and master star catalogs for stars that will be visible in the field of view of the CSA and transforming the catalog information into the required reference frame and coordinate system. The application will be modeled after two GE ASD heritage programs, named SWATH and MASTER, to perform the processing needed to generate a star catalog.

The outcome from the use of this application is a star catalog valid for up to 27 days which accounts for actual or apparent stellar motions and celestial sensor interference caused by Mars or other planets in the field of view. The star catalog can be uplinked to the spacecraft by the spacecraft ground support teams.

4.4.5.4.2.2 Input Requirements

Generation of an onboard flight star catalog requires as input:

(1) Non-telemetry data which consist of:

- Date of s/c launch.
- Mission phase.
- Flight AACS mode (e.g. sun coning, array normal spin, or mapping).
- Orbital parameters that describe the orbit and position of s/c.
- Magnitude threshold for object detection.
- Master star catalog.

(2) Operator input specifying the start, end, and midpoint dates over which time the flight star catalog is valid for s/c positioning.

4.4.5.4.2.3 Processing Requirements

Generation of an onboard flight star catalog requires two primary steps:

(1) Produce a master star catalog that is valid for one year and contains stars above a magnitude threshold.

(2) Generate an extended swath star catalog that is valid for a specified time period of up to four weeks. The extended swath generation involves:

- Calculation of the Earth position and velocity vectors.
- Calculation of the s/c position and velocity vectors.
- Calculation of the s/c spin vectors for specified mission phase.
- Construction of reference frame matrices that allow transformation to and from the J2000 coordinate system.
- Approximate positions of the Sun, Moon, and Planets.
- Reduction of star data for daily swath processing.
- Daily star swath tailoring to eliminate invalid references.
- Merge daily swaths to generate extended swath.

4.4.5.4.2.4 Output Requirements

The output from this application is a file that contains all required flight software parameters (e.g. desired memory values) for specifying an extended swath flight star catalog upload to the s/c. The file shall be deposited in the PDB and made available to the Planning and Sequencing Team (PST) for uplink generation. The star catalog shall be valid for a specified time interval from three to twenty-seven days.

4.4.5.4.3 Ephemeris Translation (TRANS)

4.4.5.4.3.1 Functional Description and Rationale

The planetary and spacecraft ephemerides uplinked to the s/c must be in a form recognized by the s/c flight software. The spacecraft team analyst responsible for the spacecraft's attitude determination and navigation shall require a software tool to translate the JPL position and velocity vectors into the flight software required format.

The SPAS Ephemeris Translation function (TRANS) will enable a spacecraft team analyst to translate JPL SPICE generated ephemeris vector data into the required form. The application will be modeled after GE ASD heritage programs developed for the translation of ephemeris data.

The outcome from the use of this application will be planetary and spacecraft ephemerides in the representative form. This information can then be uploaded to the spacecraft for attitude control and navigation.

4.4.5.4.3.2 Input Requirements

The required input for this application will be the SPK Navigation file which contains the spacecraft and planetary ephemerides. The spacecraft team analyst would retrieve this file from the PDB and subsequently process it using the JPL SPICE software tools.

Also required will be the analyst's input of epoch time, a specified target, a specified observer, a reference frame, the particular spacecraft (i.e. Mars Observer), and an aberration flag.

4.4.5.4.3.3 Processing Requirements

In cruise phase, the application will take the supplied planetary ephemeris, which contains the position and velocity vectors for the Sun and the Earth, and convert it into two 3x4 matrices of coefficients. Both the Earth and Sun will be specified in the Earth centered Earth mean equator and equinox of J2000 (EME2000).

In mapping phase, the application will take the supplied planetary ephemeris and convert it into a 3x4 matrices of coefficients in the Mars centered Mars mean equator and International Astronomical Union (IAU) vector of arbitrary time (M coordinate system).

Both the cruise and mapping conversions of ephemerides will use a least squares fit to a cubic polynomial. In addition, for mapping phase, the spacecraft ephemeris will be converted to a 3x15 matrix of coefficients giving spacecraft position in the M coordinate system.

4.4.5.4.3.4 Output Requirements

The output from this application is a file that contains all required flight software parameters (e.g. desired memory values) for specifying the planetary and spacecraft ephemerides uploads to the s/c. The file shall be deposited in the PDB and made available to the PST for uplink generation.

4.4.5.4.4 Maneuver Roll Angle Diagnostics (ROLLOPT)

4.4.5.4.4.1 Functional Description

The Maneuver Roll Angle Diagnostics (ROLLOPT) program calculates, for each user specified roll angle, diagnostic angles (e.g. solar array to sun, LGA to earth) and effective thrust direction transformations (e.g. from J2000 xyz to s/c body coordinates) at incremental points throughout a simulated burn. This information allows the SCT analysts to select the roll angle most advantageous for s/c power and communication considerations during maneuvers.

4.4.5.4.4.2 Input Requirements

The maneuver roll angle diagnostic function shall require as input:

(1) Non-telemetry data that consist of:

- Initial thrust direction
- Maneuver start time
- Pitch axis
- Pitch rate
- Sun vector in s/c body frame
- Earth vector in s/c body frame
- E to M transformation matrix

(2) Operator input specifying:

- Roll angles
- Instrument vectors
- Pitch duration
- Pitch time step
- File names
- Operational flags
- Effective thrust direction
- Thruster configuration

4.4.5.4.4.3 Processing Requirements

This function shall generate the following information for each specified roll angle:

(1) Transformation matrix from J2000 to s/c body frame.

(2) Solar array to sun angle.

(3) LGA to earth angle.

(4) Angles for any user specified vector combinations.

(5) Uplink quaternion.

4.4.5.4.4.4 Output Requirements

The output shall consist of a file that contains diagnostic angles and transformation matrices as specified above.

4.4.5.4.5 Maneuver Simulation (MANUVR)

4.4.5.4.5.1 Functional Description

The Maneuver Simulation (MANUVR) program simulates the JPL Navigation Team's specified maneuver design and generates parameters (e.g. nominal burn time, fuel used) required for eventual maneuver implementation.

4.4.5.4.5.2 Input Requirements

The maneuver simulation function shall require as input:

(1) Static data which consist of:

- Nominal thrust level for each thruster
- Nominal specific impulse for each thruster
- Gravitational acceleration

(2) Non-telemetry data which are updated after each maneuver and consist of:

- Blowdown pressure for monopropellant system
- Duty cycle for each thruster
- Efficiency factor for each maneuver thruster configuration
- S/C total mass
- Maneuver name
- Desired delta v

(3) Operator input specifying:

- Roll angle
- File names
- Operational flags
- Effective thrust direction
- Thruster configuration

4.4.5.4.5.3 Processing Requirements

The maneuver simulation function shall perform the following calculations:

(1) Calculation of the mass flow rate for each thruster used in the maneuver.

(2) Calculation of the total mass flow rate for the maneuver.

(3) Calculation of the effective specific impulse for the maneuver for all thrusters, collectively that contribute to delta v.

(4) Calculation of the effective thrust magnitude for the maneuver for all thrusters, collectively that contribute to delta v.

(5) Calculation of fuel usage.

(6) Calculation of the delta v.

(7) Calculation of the change in mass for the desired delta v.

(8) Calculation of the burn duration.

4.4.5.4.5.4 Output Requirements

The output shall consist of a file that contains output from all of the calculations listed above. In addition, this function shall generate a Maneuver Implementation/Reconstruction file consistent with the format specified in the appropriate JPL SIS.

4.4.5.4.6 Maneuver Reconstruction (RECON)

4.4.5.4.6.1 Functional Description

The Maneuver Reconstruction (RECON) program reconstructs key parameters that describe the completed maneuver (e.g. burn duration, fuel used, achieved delta v) and those parameters that are used for planning future maneuvers (e.g. updated duty cycles, accelerometer efficiency).

4.4.5.4.6.2 Input Requirements

The maneuver reconstruction function shall require as input:

(1) S/C telemetry that consist of:

- Total thruster on times that indicate the firing status of each bipropellant engine.
- Total thruster on times that indicate the firing status of each monopropellant engine.
- Accelerometer raw data and integrals.

(2) Non-telemetry data consisting of:

- Thruster combinations.
- Thrust and Isp values.
- Efficiency values.
- S/C mass.

(3) Operator input specifying the following:

- File names.
- Operational flags.
- Time interval and sampling frequency for the required telemetry points for subsequent processing of retrieved telemetry file. Telemetry file retrieval is assumed to have already occurred.

4.4.5.4.6.3 Processing Requirements

The maneuver reconstruction function shall perform the following calculations:

(1) Calculate the burn duration.

(2) Calculate the total delta v magnitude.

(3) Calculate the total delta v direction.

(4) Calculate the thruster duty cycles.

(5) Calculate the accelerometer efficiency.

(6) Calculate the thruster flowrates.

(7) Calculate the mass loss.

4.4.5.4.6.4 Output Requirements

The output shall consist of a file that identifies the reconstructed maneuver and contains output from all of the above calculations.

4.4.5.4.7 Thruster Efficiency Calculation (THRUST)

4.4.5.4.7.1 Functional Description

The Thruster Efficiency (THRUST) program calculates the thruster efficiency for any past maneuver. The efficiency is a measure of the thrust produced by the group of thrusters contributing to delta v for the maneuver.

4.4.5.4.7.2 Input Requirements

The thruster efficiency function shall require as input:

(1) Non-telemetry data that consist of:

- Observed burn duration reconstructed from telemetry.
- Observed delta v from tracking data.
- Calculated delta v using observed burn duration.
- Thrust and Isp values for each thruster.

4.4.5.4.7.3 Processing Requirements

The thruster efficiency function shall perform the following calculations:

(1) Update thrust efficiency for maneuver thruster configuration.

(2) Refine all thruster quantities (e.g. thrust, Isp, flowrates).

4.4.5.4.7.4 Output Requirements

The output shall consist of a file that contains updated thruster characteristics for all delta-v thrusters used in the maneuver.

4.4.5.4.8 Maneuver Mass Loss (MASSLOSS)

4.4.5.4.8.1 Functional Description

The Maneuver Mass Loss (MASSLOSS) program distributes the total delta mass consumed during the previous maneuver to each of the propellant tanks. In addition, the program updates the delta-v thruster duty cycles, maneuver efficiency, and accelerometer efficiency found in the maneuver reference file.

4.4.5.4.8.2 Input Requirements

The maneuver mass loss function shall require as input:

(1) Non-telemetry data that consist of:

- Mass tank ratios derived from the TANKS program.
- Duty cycles
- Accelerometer efficiency
- Maneuver efficiency

(2) Operator input specifying the following:

- File names
- Operational flags
- Oxidizer/Fuel mixture ratio

4.4.5.4.8.3 Processing Requirements

This function shall calculate the following:

(1) Mass loss for each tank using tank mass ratios from TANKS

(2) Mass loss for each tank using Oxidizer/Fuel mixture ratio

(3) Mass loss for each tank using an operator entered ratio

4.4.5.4.8.4 Output Requirements

The output shall consist of a file that contains mass loss by tank.

4.4.5.4.9 Maneuver Performance Update (UPDATE)

4.4.5.4.9.1 Functional Description

The Maneuver Performance Update (UPDATE) program updates the parameters found in the Maneuver Performance Data File. These parameters are used by the SCT and the JPL Navigation Team for maneuver design.

4.4.5.4.9.2 Input Requirements

The maneuver performance update function shall require as input:

(1) Non-telemetry data that consists of:

- Propellant flow rate for each thruster
- Effective thrust magnitude for only those thrusters contributing to delta v for a given maneuver thruster configuration
- S/C total mass
- S/C center of mass
- S/C moments of inertia

(2) Operator input specifying the following:

- File names.
- Operational flags.

4.4.5.4.9.3 Processing Requirements

This function shall update the Maneuver Performance Data file. The specific parameters to be updated are as follows:

(1) S/C total mass.

(2) Propellant flow rate for each thruster

(3) Effective thrust magnitude

(4) S/C moments of inertia

(5) S/C center of mass

4.4.5.4.9.4 Output Requirements

The output shall consist of an updated Maneuver Performance Data File in accordance with the MPDF JPL SIS.

4.4.5.5 Command and Data Handling (C&DH)

4.4.5.5.1 SSR Data Management (SSR_DM)

4.4.5.5.1.1 Functional Description

THE REQUIREMENTS FOR THIS SOFTWARE ARE TBD.

4.4.5.5.1.2 Input Requirements

4.4.5.5.1.3 Processing Requirements

4.4.5.5.1.4 Output Requirements

The output shall consist of a file that contains:

4.4.5.5.2 Command Verification Monitor (CV_MON)

4.4.5.5.2.1 Functional Description

THE REQUIREMENTS FOR THIS SOFTWARE ARE TBD.

4.4.5.5.2.2 Input Requirements

4.4.5.5.2.3 Processing Requirements

4.4.5.5.2.4 Output Requirements

The output shall consist of a file that contains:

4.4.5.6 Telecommunications Subsystem (Telecom)

The Telecommunications Performance Analysis Subsystem (TPAS) shall process engineering data to provide communications link predictions, profiles of probability of data return, and performance comparisons. TPAS consists of two program sets to perform these tasks: 1) Telecommunications Prediction and Analysis Program (TPAP) and 2) Mars Global Surveyor Telecommunications On-line Processing System (MTOPS).

4.4.5.6.1 Telecommunications Prediction and Analysis Program (TPAP)

4.4.5.6.1.1 Functional Description

TPAP is the portion of TPAS that generates performance predictions. TPAP shall be written in a high level, block structured language and shall execute on a VAX series computer during mission operations. TPAP shall contain a MGS-specific link parameter database having the latest MGS spacecraft and Deep Space Station parameters needed for the communication link computations. This database shall be maintained under Unisys 1100 TPAP software control. A read-only version shall be used during execution of TPAP for prediction generation.

This function shall compute telecommunications link performance: 1) for medium and long range planning of telemetry channel usage requirements, 2) for short and medium range profiles of telemetry data rate probability, 3) for link design and analysis, 4) for spacecraft maneuver and sequence evaluation, and 5) for anomaly investigation.

4.4.5.6.1.2 Input Requirements

(1) Station and Earth-centered trajectory related values in Chebyshev polynomial coefficient form (STATRJ) from the NAV team.

(2) Predicted spacecraft high gain antenna pointing vector as a function of time during spacecraft maneuvers from AACS.

(3) Time-ordered listing of station profile activities which describe the configuration of the telecom link (TCRF).

4.4.5.6.1.3 Processing Requirements

(1) This function shall compute expected received command and telemetry carrier power levels, command, and telemetry, signal-to-noise ratios, bit error rates, expected statistical tolerances, and link margins.

(2) TPAP shall perform the following performance prediction processing:

- Prediction: Predict communication link capability for specified times and spacecraft/ground station configurations. These predictions shall include downlink tracking and telemetry data, and uplink carrier tracking and telemetry data. The predictions shall show the confidence level of data return, including the effects of weather.

- Profiling: Produce a file of the percentage data return for various confidence levels for a specified sequence of spacecraft/ ground station configurations. Each profile shall be for a specified RF band, data type, data return confidence level, and weather model.

(3) TPAP shall accept spacecraft trajectory data as input.

- Precision trajectory data for the spacecraft when sun and Earth oriented. This input is the Station Polynomial Coefficients file (STATRJ) from the Navigation Team.

- Cone and Clock Angle data for the S/C during off-Earth line maneuvers when normal HGA pointing to the Earth does not exist. This file shall be used in conjunction with STATRJ file and is generated by the Spacecraft Team.

(4) TPAP shall accept link allocation information as input.

- Telemetry Capability Request File (TCRF) which is a Standard Sequence Data Files (SSDFs) containing time-ordered listings of ground station profile activities which describe the configuration of the telecom link.

(5) TPAP shall provide the following kinds of output for the prediction processing function:

- Design Control Tables (DCT) for carrier tracking, command, and telemetry. DCTs provide a listing of all link parameters and their tolerances for a given user-specified configuration and point in time.

- Tabulations and plots of design-point and adverse case carrier, command, and telemetry predicted performance versus time, as specified by the user.

- A file of uplink carrier, downlink carrier and telemetry parameters versus time, for use by the on-line comparison software. This file shall be transportable between the TPAP computer and the MTOPS. It is internal to the Telecom Performance Analysis Subsystem.

- Diagnostic narrative. TPAP shall provide narrative descriptions of all abnormal conditions encountered during its operation. Anomalous conditions reported shall include errors in the user control input, errors in input files and errors encountered while trying to generate prediction data.

(6) TPAP shall provide the following kinds of output for the profiling processing function:

- Telemetry Performance File (TPF) containing the probability of telemetry data return for X-band downlink as a function of time shall be provided.

- Hardcopy plots and tabulations shall be available as required of the data rate and capability profile.

4.4.5.6.1.4 Output Requirements

The output shall consist of:

(1) Data files, and display and hardcopy versions of plots, design control tables and tabulations.

4.4.5.6.2 On-Line Telecom Link Comparisons (MTOPS)

4.4.5.6.2.1 Functional Description

MTOPS is the portion of TPAS that compares predicted link quantities with actual (observed) link quantities. Link quantities compared shall include both configuration and performance items. Results of the comparison shall include link residuals, alarms and statistics of the residuals.

To generate on-line comparisons of actual performance data and link predictions for monitoring telecom subsystem performance, for anomaly detection and correction, and for generating telecom subsystem performance summaries for periodic management reports.

4.4.5.6.2.2 Input Requirements

(1) Actual spacecraft telemetry data.

(2) Actual DSN performance data.

(3) File containing telecom link configuration data and link performance data generating by TPAP.

4.4.5.6.2.3 Processing Requirements

(1) This software shall perform on-line comparisons between predicted and actual link parameters for the uplink received carrier power (AGC), command channel signal-to-noise ratio (SNR), downlink received carrier power for X-band, telemetry bit and symbol signal- to-noise ratios for convolutional coded data, measured bit error rate, system noise temperatures for X-band downlink. Results of the comparison shall include link residuals, alarms, and statistics of the residuals.

(2) MTOPS shall accept as input telecom link configuration data and link performance data generated by TPAP. This input shall be transportable between the TPAP computer and the MTOPS.

(3) MTOPS shall accept as input real-time spacecraft telemetry and DSN monitor data via an electrical interface with the Data Acquisition and Command Subsystem.

(4) MTOPS shall provide the following kinds of output for the comparison processing function:

a) MTOPS archival file containing actual data, residual data, and statistics. It is internal to TPAS.

b) Terminal displays of residuals shall be output as they are generated.

c) Plots of user-specified parameters versus time shall be available as terminal displays or as hardcopy plots.

d) Printed outputs shall include:

- Pass summary containing statistics of the residuals.

- Tabulations of predictions, actuals and residuals from the MTOPS archival file.

- Self-documentation of MTOPS status and error messages during on-line operation.

e) MTOPS shall provide link residual alarms to flag out-of-tolerance limit conditions and status error messages to indicate when the actual link configuration differs from the assumed configuration upon which the predicted performance is based.

4.4.5.6.2.4 Output Requirements

The output shall consist of:

1) Data files, and display and hardcopy versions of plots, tabulations, pass summaries, and MTOPS status and error messages.

4.4.5.7 Flight Software Management

In order to support the capability to update flight software, all flight software development tools will be maintained post launch. Flight software loading capabilities to interface the raw flight-code language processor outputs (load modules) to the uplink system (PSS) will also be provided. This section describes all tools that will be used to track and management flight software during flight operations.

4.4.5.7.1 Memory State Tracking (MST)

4.4.5.7.1.1 Functional Description

This function shall provide the capability to accurately track the contents of on-board memory contents and compare the tracked contents against the actual S/C memory contents that is obtained via a S/C Memory Read-Out (MRO).

4.4.5.7.1.2 Input Requirements

(1) MRO telemetry from the S/C
(2) MEMFIL produced by SEQTRAN
(3) Flight Software Memory File
(4) S/C Parameter Mask File
(5) Run Control parameters.

4.4.5.7.1.3 Processing Requirements

(1) MST shall be able to access as an input the files of telemetry measurements produced by the Data Acquisition and Command Subsystem. The data will be identified by a special MRO buffer in the case of memory readout data.

(2) Telemetry data gaps or spikes within a telemetry file shall not interrupt data processing. MST shall fill all telemetry data gaps and force miscompares.

(3) These modules shall permit interactive input of processing and output control parameters. The user shall be prompted for these input variables.

(4) The sources of Memory Mask files which MST shall access are the Cumulative Memory Map File (MEMFIL) (maintained by the SEQTRAN Program), the Flight Software Memory File (FSMF) (maintained by Flight S/W Development) and the S/C Tracked Parameters Mask File.

(5) MST shall be able to access normal Memory Readout data from a special MRO file created by the Data Acquisition and Command Subsystem, and reformat the file as necessary to match the format of the selected Mask file.

(6) MST shall access the Flight Software Memory File contents file and compare it word-for-word with an MRO file. Any differences shall generate a printout identifying the memory, the specific address for the miscomparison, and both the Flight Software Memory File contents and the MRO contents for that address.

(7) MST shall permit memory analysis and comparison to be performed on either sequencing memory locations or on flight software memory locations or on parameter memory locations, using the appropriate memory mask ground file.

4.4.5.7.1.4 Output Requirements

The output shall consist of a file that contains:

(1) Number of words processed and compared.
(2) Number of miscompares.
(3) Address of each miscompare and content of both the telemetry file and memory map at that address

4.4.5.7.2 Parameter Tracking (PARM_TRK)

4.4.5.7.2.1 Functional Description

This program, designated PARM_TRK, will handle the tracking of changes to on-board flight software parameters, variables, data items and table entries. This function will maintain an up-to-date ground copy of all flight software parameters as they appear on-board the spacecraft and produce associated reports and mask files.

4.4.5.7.2.2 Input Requirements

(1) PEF containing Flight Software parameter update requests including parameter location, new value and time of change.
(2) Master data base containing the previous spacecraft parameter state.
(3) Output options for displaying or reporting subsequent data base content.
(4) Flight Software Parameters (file or interactively).
(5) Current Flight Software memory mask file (optional)

4.4.5.7.2.3 Processing Requirements

(1) A master data base shall be created which contains all identified parameters by name, memory device, memory location, time-of-change and current value. This data base shall have two access keys at a minimum, location and name. Ancillary attributes of each parameter name may include data type, dimension, units, hex-equivalent-value and size.

(2) The master data base shall be maintained so that the "current values" set represents the actual state of the spacecraft parameter memory areas at all times.

(3) The PARM_TRK shall use the PSS-produced Predicted Events File (PEF) as its source of update transactions to maintain data base accuracy. The update transaction keys on the PEF shall be consistent with the way sequence components effect parameter changes.

(4) The PARM_TRK shall have options to print the entire data base, or only those records that have changed since a user-specified date and time. In addition, any portion of the data base shall be viewable directly on the CRT without hardcopy.

(5) The PARM_TRK shall be the data base content maintenance program. As such it shall operate on any specific data base version.

(6) The PARM_TRK shall allow the creation of a file containing hexadecimal parameter values-by-address (mask file).

(7) This PARM_TRK have the capability to overlay the mask file created in Step 7 over a current memory mask at user option.

4.4.5.7.2.4 Output Requirements

The output shall consist of a file that contains:

(1) Entire data base
(2) Changes only
(3) All record changes since a given date and time
(4) last Values-by-address (ascending address order)
(5) last Value-by-name (alphabetic)
(6) update current memory Mask File(optional)

4.4.5.7.3 Flight Software Load (FSLOAD)

4.4.5.7.3.1 Functional Description

This program, designated FSLOAD, will handle the reformatting flight software loads to the Desired Memory Words File (DMWF) format for PSS input. The program will also handle updates to the baseline Flight Software Memory File (FSMF).

4.4.5.7.3.2 Input Requirements

(1) Flight Software Memory File(s)

4.4.5.7.2.3 Processing Requirements

(1) FSLOAD shall accept as input flight software load files representing the hexadecimal images of flight software code.

(2) FSLOAD shall format the flight software load files into DMWFs representing general memory load commands for input into SEQTRTAN.

(3) FSLOAD shall update the baseline FSMFs used by the MST program each time a flight software modification is made.

4.4.5.7.3.4 Output Requirements

(1) DMWFs.
(2) Updated baseline Flight Software Memory Files.

4.4.5.7.4 Flight Software Maintenance

4.4.5.7.4.1 Functional Description

This section is TBD.

This section will describe the Micro Vax Flight Software Maintenance environment that will transition from development into operations to support in-flight, flight software maintenance.

4.4.5.7.4.2 Input Requirements

4.4.5.7.4.3 Processing Requirements

4.4.5.7.4.4 Output Requirements

4.4.5.8 Systems Engineering

4.4.5.8.1 TBD

4.4.5.5.1.1 Functional Description

THE REQUIREMENTS FOR THIS SOFTWARE ARE TBD.

4.4.5.5.1.2 Input Requirements

4.4.5.5.1.3 Processing Requirements

4.4.5.5.1.4 Output Requirements

The output shall consist of a file that contains:

4.4.5.9 EAS Utilities

4.4.5.9.1 Telemetry Dictionary Editor (TDE)

4.4.5.9.1.1 Functional Description

TDE will be the information base which maintains spacecraft specifics on mnemonics, calibration factors, and decommutation maps for use in AMMOS-provided workstations to process incoming spacecraft telemetry.

TDE shall be a data base which will allow for the definition and interpretation of the engineering telemetry data by Team members and by the Data Acquisition and Command Subsystem.

4.4.5.9.1.2 Input Requirements

(1) For each telemetry channel, a respective position in the commutation tree and the telemetry channel type.
(2) dn to eu conversion/factors in the form of a 5th order polynomial,
(3) or a 16 point lookup interpolation table or string equivalent, and alarm limits from each SCT unit.

4.4.5.9.1.3 Processing Requirements

1. A Macintosh microcomputer shall be the interface device for creating, manipulating or updating TDE information.

2. TDE shall contain at a minimum the tables which define for each telemetry channel, a respective position in the commutation tree, the required data number to engineering unit conversion polynomial, lookup table or string equivalent, and default upper and lower alarm limit values. The data provided in MCR-94-4130 (Telemetry Dictionary) and MCR-tbd (Telemetry Calibration Report) are sources for these tables.

3. Dn to eu conversion and calibration factors and default alarm limits shall be provided by each SCT unit (i.e., propulsion, power, thermal, AACS, C&DH and Telecom).

4. All tables which constitute TDE shall be recordable on magnetic media for computer access and readable by AMMOS software.

5. Hardcopy report generation shall be provided to create listings in flexible formats for ease of use by Team members.

4.4.5.9.1.4 Output Requirements

The output shall consist of a file that contains:

(1) Table in machine-readable format of telemetry interpretation information that is stored in the DACS and acceptable to the AMMOS-provided Telemetry workstation. Hard-copy printouts with convenient format variations (i.e., sorted by commutation position, subsystem or name).

4.4.5.9.2 EAS Plotting

4.4.5.9.1.1 Functional Description

The utility program, VMPLOT, consists of a screen plot and hard copy function which will be used to satisfy the plotting requirements of the various EAS Analysis and Prediction programs.

4.4.5.9.1.2 Input Requirements

(1) Data Return File,
(2) Control File

4.4.5.9.2.3 Processing Requirements

1. The VMPLOT program shall be written in a higher order language and shall execute on the SUN workstation.

2. The VMPLOT program shall accept a telemetry file as input. This input file is produced by the Data Acquisition and Command Subsystem.

3. The VMPLOT program shall accept a file containing Analysis or Prediction plot data as input. This file is produced by the various SPAS programs which require plotting capabilities.

4. The VMPLOT program shall accept a file containing plot control parameters. This file is produced by the various SPAS programs requiring plotting capabilities or may be generated using an editor.

5. The VMPLOT program shall use the information contained within the control parameters file to format the plot image from data contained within the telemetry file and/or SPAS data file.

6. The VMPLOT program shall be capable of producing either a screen image or an 11" x 8 1/2" hard copy image. If a screen image is produced, the capability to produce a hard copy of the displayed image shall also be provided.

7. The VMPLOT program shall be capable of overplotting data contained within the same or two different data files. All x/y data pairs will come from the same file.

8. The VMPLOT program shall be capable of producing either a channel vs. time or a channel vs. channel plot.

9. The VMPLOT program shall be capable of overplotting up to 4 separate channel vs. time plots per image. Plot characteristics and a key shall be provided to differentiate the multiple plots.

10. The VMPLOT program shall be capable of overplotting up to 4 separate channel vs. channel plots per output image. Plot characteristics and a key shall be provided to differentiate multiple plots.

11. Plot start and end time (or point) information shall be indicated on channel vs. channel plots.

12. The VMPLOT program shall indicate with symbols the data start point on channel vs. channel plots

13. The VMPLOT program shall have an optional auto-scale or manual-scale capability for channel data axis(es).

14. The VMPLOT program shall have an option of selecting between an absolute or a relative time scale for channel vs. time plots. If the relative time scale is chosen, the epoch time shall be indicated on the plot.

15. The VMPLOT program shall have an optional logarithmic scale capability.

16. The VMPLOT shall provide axis/grid indicators.

17. The VMPLOT program shall have the following data display options:
    a) Point plot (using symbols to distinguish data)
    b) Line plot (straight lines connecting data points)
    c) "Strip Chart" plot (data points connected by horizontal and vertical lines)

18. The VMPLOT image shall also contain, at a minimum, the following ancillary data:
    a) Plot title
    b) X and Y axis labels
    c) Name of data files used in generating the plot
    d) Date and Time of plot generation
    e) VMPLOT software version notice

4.4.5.9.2.4 Output Requirements

(1) Hard Copy or Screen Plots

4.4.5.10 Offline Analysis Software

The following table contains a list and brief description of all EAS offline Analysis software.

EAS Offline Analysis Software

Item	Description

TBS

4.4.6 INTERFACES

This section contains a discussion of the frequently used electrical data interfaces used by the Engineering Analysis Subsystem. Information concerning EAS non-electrical interfaces (paper) and one time only (infrequent) electrical interfaces can be found in Operational Interface Agreements. Included herein are estimates of data volumes and frequencies to provide traffic requirements across these interfaces. These estimates are based upon a variety of assumptions, many of which are subject to change as the interface design matures. These assumptions are stated in the text and/or in footnotes in the accompanying tables.

4.4.6.1 EAS Software Interface Specifications

This section identifies the required EAS interfaces with other subsystems within the GDS. Table 4.4.6-1 describes interfaces which are generated by the EAS, whereas Table 4.4.6-2 describes the interfaces received by the EAS. These tables contain the Software Interface Specification (SIS) ID; the file's title, generating program; and subsystem and the receiving subsystem and program.

Table 4.4.6-1 EAS Generated SIS's

SIS ID	TITLE	GEN. S/S	GEN. PROG	REC. S/S	REC. Prog
EAS-003	Angular Momentum Desaturation File	EAS	tbd	NAS	tbd
EAS-008	Maneuver Performance Data File	EAS	tbd	NAS	tbd
EAS-011	NAV Eng Information File	EAS	tbd	NAS	tbd
EAS-014	Maneuver Implementation /	EAS	tbd	NAS	tbd
	Reconstruction File				
EAS-017	Stream Data Extract Command	EAS	tbd	DSR	tbd
	Line Input I/F				
EAS-018	Database Catalog Command	EAS	tbd	DSR	tbd
	Line Input I/F				
DACE029	**Decom Map**	**EAS**	**TDE**	**DAC, SSS**	**TIS, DMD**
DACE016	**Engr Channel Parameter Table**	**EAS**	**TDE**	**DAC**	**TIS, DMD**
DACE017	**Channel Conversion Language File**	**EAS**	**TDE**	**DAC**	**TIS, DMD**
DACE002	**Command Database**	**S/C team**	**author**	**DAC, PSS**	**ACT, SEQ**

Table 4.4.6-2 SIS's Received by the EAS

SIS ID	TITLE	GEN. S/S	GEN. PROG	REC. S/S	REC. Prog
DACE-001	DSN Viewperiod File	DACS	tbd	EAS	tbd
DACE-011	Raw DSN Monitor Blocks	DACS	tbd	EAS	tbd
DACE-013	Channelized Monitor Data	DACS	tbd	EAS	tbd
DACE-014	DSN Telecom Performance Predicts	DACS	tbd	EAS	tbd
DACE-020	Daily Detailed Command Report	DACS	tbd	EAS	tbd
DACE-037	ECDR	DACS	tbd	EAS	tbd
DACE-040	S/C Eng Tlm Pkt Data Record	DACS	tbd	EAS	tbd
DACE-042	Command Translation Table	DACS	tbd	EAS	tbd
DSR-011	Raw Data Query Results File	DSR	tbd	EAS	tbd
DSR-012	QQC Summary Report File	DSR	tbd	EAS	tbd
DSR-013	Database Catalog Search Results File	DSR	tbd	EAS	tbd
DSR-017	Spacecraft Clock Coefficient File	DSR	tbd	EAS	tbd
NAE-001	Station Polynomial File	NAS	tbd	EAS	tbd
NAE-002	Light Time File	NAS	tbd	EAS	tbd
NAE-003	Orbit Propagation & Timing	NAS	tbd	EAS	tbd
	Geometry File				
NAE-006	Maneuver Profile File	NAS	tbd	EAS	tbd
NAE-008	Astrodynamic Constants &	NAS	tbd	EAS	tbd
	Init Cond File				
NAE-011	S & P Kernels File	NAS	tbd	EAS	tbd
PSE-001	Predicted Events File	PSS	tbd	EAS	tbd
PSE-002	Sequence of Events File	PSS	tbd	EAS	tbd
PSE-003	Space Flight Operations Schedule	PSS	tbd	EAS	tbd
PSE-008	Sequence Memory Map	PSS	tbd	EAS	tbd
PSE-010	S/C Activity Sequence File	PSS	tbd	EAS	tbd
PSE-013	Desired Memory Word File (DMWF)	PSS	tbd	EAS	tbd
SSE-004	Instrument Status Report File	PSS	tbd	EAS	tbd
SSE-005	Instrument Power Profile File	PSS	tbd	EAS	tbd
VTL-002	VTL Sequence Output File	STL	tbd	EAS	tbd
VTL-003	VTL Miscompare Sequence Events FileVTL-003	STL	tbd	EAS	tbd
VTL-004	VTL Memory Dump File	STL	tbd	EAS	tbd
VTL-005	VTL Simulation Run Log	STL	tbd	EAS	tbd

4.4.7 REQUIREMENTS TRACEABILITY

The Level 4 EAS requirements specified in this Functional Requirements Section reflect the EAS requirements specified in Section 3.4.9 of this document. The following Traceability Matrix provides a trace from the requirements listed in Section 3.4.9 to the requirements documented by section 4.4.

TRACEABILITY MATRIX

Section 4.4 Requirement	**Description**	**Higher Level Requirement**

TBS

4.4.8 TEST REQUIREMENTS

Testing of inherited and implemented software shall be the responsibility of the Cognizant Engineer (CEs) with the aid of the EAS Subsystem Engineer. The goal of this activity is to ensure that the developed software complies with the software requirements and interfaces that have been documented for each module. The following paragraphs describe the test process.

At scheduled periods during the implementation process, the Cognizant Programmer (CP) shall prepare test plans, procedures and test data to perform unit testing to verify proper operations of the software. Test data will consist of actual information, where known, applicable MGS S/C ATLO data or manually computed data. Unit testing shall check that all logic branches of the software operate correctly, all equations and algorithms provide the correct arithmetic results, all data sources are accessed correctly and all outputs are provided in the correct and proper formats.

The CEs shall write the Subsystem User Acceptance Test Plan (SATP), with the guidance of the EAS Subsystem Engineer, using the Software Requirements Document and Software Interface Specifications as source information to test against the Function Requirements described in this document. The SATP shall specify the testing philosophy, rationale, organization and acceptance criteria and shall identify any prerequisites and priorities for the conduct of the test cases.

Following the development of the SATP, the CEs shall identify the detailed test procedures to be used for each test case. These procedures shall identify the attributes of all input data required, user control inputs and expected outputs for each test case.

The CEs shall conduct the user acceptance testing of the unit-tested software according to the SATP and detailed test procedures.

Upon the successful completion of the acceptance testing, the CEs shall write a test report which summarizes the test activities and identifies any liens against the accepted software and the scheduled date when these liens shall be cleared.

The CEs shall also generate a regression baseline test case to be included with the software when it is delivered to mission operations. This test case shall be executed during GDS testing to verify that the software was not altered during the interim period.

4.5 DATA ACQUISITION AND COMMAND SUBSYSTEM

This section specifies the functional capabilities required of the Data Acquisition and Command Subsystem (DAC). These capabilities will generally be provided by the Mission Operations Support Office (MOSO) and the Deep Space Network (DSN), with the exception of some project-provided databases.

4.5.1 Introduction

The Data Acquisition and Command Subsystem of the Mars Global Surveyor Data System provides for a wide variety of uplink and downlink functions. The DAC is composed of six major subsystems:

1. Telemetry
2. Command
3. Monitor
4. Simulation
5. Tracking & Radio Science
6. Mission Control and Data Management

A brief summary of the function of each subsystem follows.

4.5.1.1 Telemetry Subsystem

The telemetry subsystem consists of hardware and software necessary for:

a) DSN to acquire the downlink telemetry signal from the spacecraft;

b) DSN to acquire the downlink telemetry signal via hardline and digital tape (via MGDS SIM)

c) DSN to synchronize, process, and format the telemetry signal into Standard Formated Data Units containing the S/C transfer frames;

d) DSN to account for and transfer the telemetry data (transfer frames) to the GCF-MGDS interface;

e) MGDS to receive the telemetry transfer frames from the GCF interface;

f) MGDS to accept, decode (Reed-Solomon), extract packets, process, decommutate, and display the received telemetry data.

g) MGDS to forward telemetry data to DSR for storage

h) MGDS to provide realtime telemetry displays.

4.5.1.2 Command Subsystem

The command subsystem consists of hardware and software necessary for:

a) The Project to generate a command database (containing command mnemonics, operational codes, parameters, data fields, and rules) and store it on the PDB for use by PSS and the MGDS Command System.

b) MGDS to allow for transfer of Spacecraft Message File (SCMF) from the PSS to the command subsystem. (Note: File transfer is supported by DSR. See 4.6.3.1)

c) MGDS to process, build, display, and forward command data to the DSN (CMD 4-6, 820-13 or MGDS-1-CMD-DSN-Cmdmsg);

d) MGDS to generate Command Processor Assembly control statements for transmission to the DSN (CMD 4-6; 820-13 or MGDS-1-CMD-DSN-Cmdmsg);

e) MGDS to display details of command processing including lists of generated commands, subsystem status, and station acknowledgments.

f) MGDS to electronically record and track the status and history of each command from its inception as a command request, through software processing and operational approval, to tranmission and verification.

Note that the Command Subsystem design for MGS includes management of SCMF files (which will have been produced by PSS), translation to Ground Command File (GCMD) format, and transmission to the DSN and spacecraft. The MGS Project does not require that MGS spacecraft commands be initiated at or composed within the MGDS Command Subsystem.

4.5.1.3 Monitor

The monitor subsystem consists of hardware and software necessary for:

a) DSN to generate, transport, process, and display tracking station monitor information parameters;

b) MGDS to process, display, and transfer for storage tracking station monitor information parameters;

c) MGDS to display status and configuration of MGDS subsystems.

4.5.1.4 Simulation

The simulation subsystem consists of hardware and software necessary for:

a) MGDS to build, display and transmit telemetry, and monitor data for MGDS testing;

b) MGDS to simulate DSN Command acknowledgements, etc., to test the MGDS Command Subsystem.

c) MGS Project to conduct testing and training programs.

4.5.1.5 Tracking and Radio Science

The tracking and Radio Science Subsystem consists of the hardware and software necessary for the:

a) DSN to acquire the spacecraft downlink carrier and track the spacecraft.

b) DSN to measure downlink carrier Doppler (in the one-way mode or two-way coherent mode) and spacecraft range, as well as, provide additional data needed to calibrate and interpret these measurements.

c) DSN to make radio science open-loop recordings of the downlink carrier and transfer open loop data to MGDS in realtime.

d) DSN to provide supplementary data on the status, configuration and performance of the Tracking and Radio Science Systems.

e) MGDS to accept, store and make accessible to the proper MGS Project users the above data products.

4.5.1.6 Mission Control and Data Management

The Mission Control and Data Management Subsystem consists of the hardware and software necessary for conversion of PSS sequence products to reviewable and operable form.

4.5.2 Functional Design

MGS relies on the multimission capabilities of the Deep Space Network and the Multimission Ground Data System for essentially all preparatory, real time, and post pass processes in support of mission operations. See figure 4.5.1 DAC Functional Block Diagram for assignment of project functions to the standard subsystems of the DSN and MGDS.

4.5.3 Detailed Functional Requirements

The following are functional requirements on the Data Acquisition and Command Subsystem. The organization that is responsible for providing the software or tools necessary to fulfill a particular requirement is listed in parenthesis at the end of the requirement.

Requirements are separated by subsystem in the following order:

A. Telemetry
B. Command
C. Monitor
D. Simulation
E. Tracking and Radio Science
F. Mission Control and Data Management

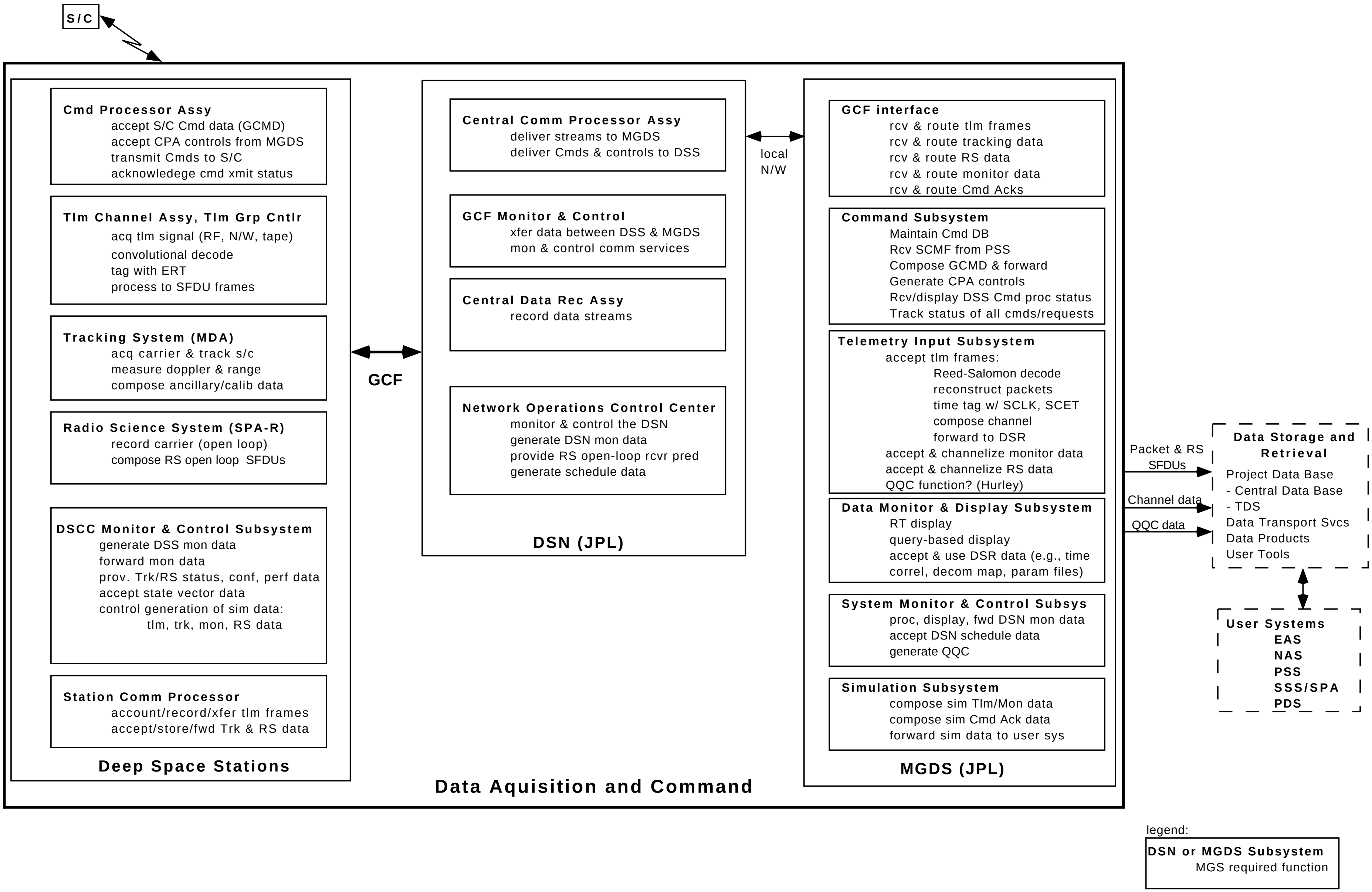


Figure 4.5.1 Data Aquisition and Command Functional Block Diagram

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4.5.3.1 Telemetry

See figure 4.5.2, Telemetry Data Flow. The Telemetry Subsystem requirements are:

a) Acquire telemetry from the MGS spacecraft

Acquire telemetry from the MGS spacecraft (all formats), via radio frequency (RF) link using telecommunications prediction data [L] and via hard-line and/or digital tape from MGDS SIM. (DSN) [D]

b) Deliver acquired telemetry data to MGDS (DSN) [D]

c) Time-tag MGS telemetry frames with ERT

Time-tag MGS data arriving at the DSN from the spacecraft with ERT resolution and accuracy of 1 millisecond. (DSN) [D]

d) Decode convolutionally encoded telemetry data. (DSN) [D]

e) Synchronize the transfer frames of all MGS telemetry formats (DSN)[D]

f) Decode Reed-Solomon encoded data

Decode Reed-Solomon (Berlekamp representation) encoded spacecraft data. (MOSO - nominal) (DSN - optionally, Ref. MRD 4.3.3.) [D]

g) Time-tag data with SCET

Time-tag each packet of MGS data with SCET. To a resolution of 1 ms, using the SCET/SCLK correlation file. (MOSO) [D]

h) Provide real time displays of telemetry stream data; up to 10 frames, packets, or records to be displayed upon operator request. This shall include any stream data plus channelized records (Snaps). Snaps shall be provided immediately following creation of the data, or entrance into the system. (MOSO) [D]

i) Extract Telemetry Packets.

Extract telemetry packets from transfer frames. Format in SFDU records. (MOSO) [D]

j) Provide data accountability information to the packet level, including counts and outages on both transfer frames and packets for all telemetry data (science and engineering). (DSN, MOSO) [L]

k) Copy the SCLK from the packets to the SFDU header. (MOSO) [D]

l) Identify telemetry packets by application I.D., SCLK, source packet sequence count and store on the PDB. (MOSO) [D]

m) Decommutate and channelize engineering data. (MOSO) [D]

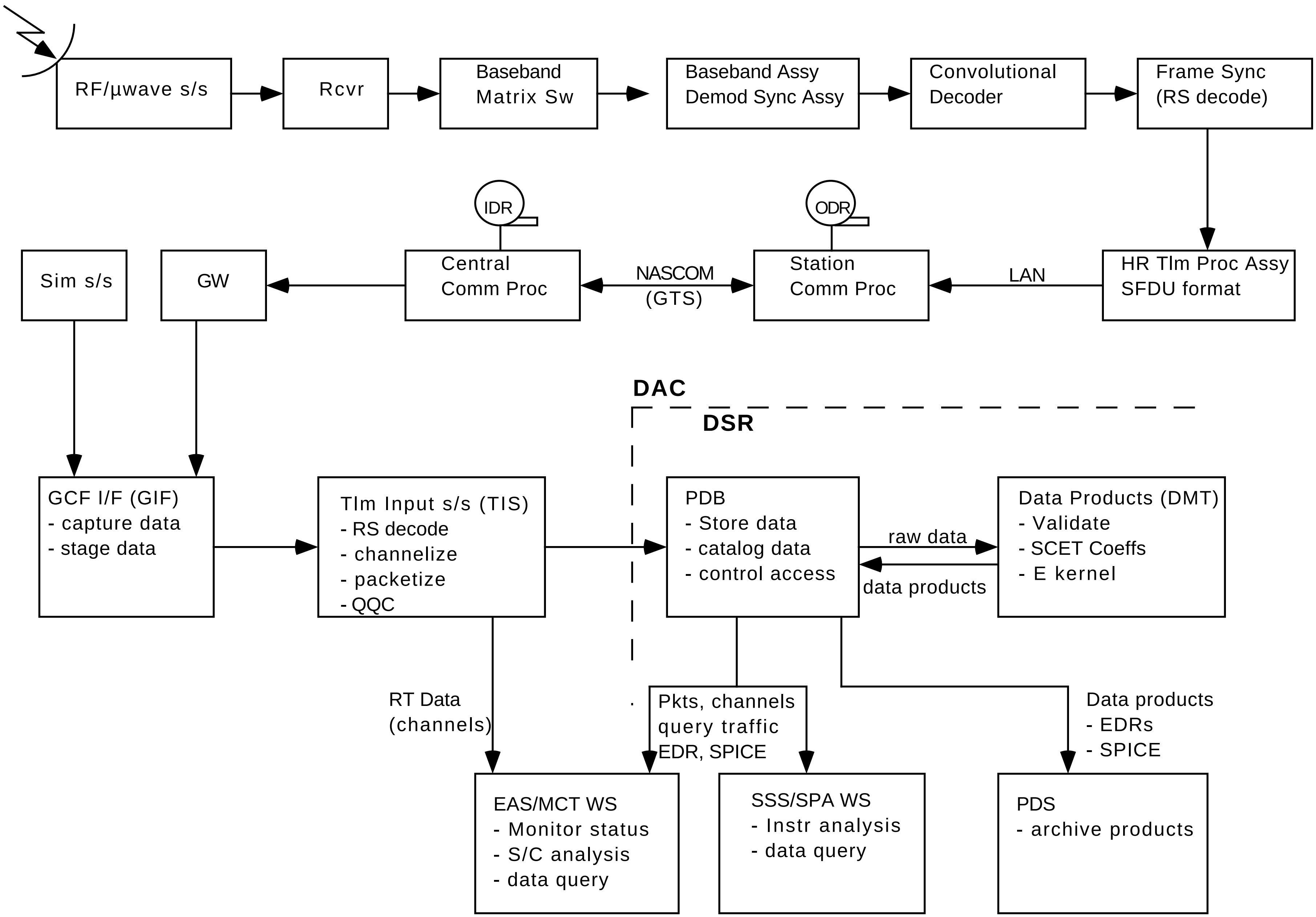

Figure 4.5.2 Telemetry Data Flow

n) Accept updated databases, including channel parameter tables (alarm limits, definitions, etc.), "dn" to "eu" conversion tables, and Decom map files. (MOSO) [D]

o) Provide a mechanism for creation of derived channels. (MOSO) [D]

p) Accept and process telemetry data from the spacecraft checkout station via TTACS (MOSO) [D]

q) Validate, Recall and Replace Data.

Validate quality of data received from the DSN. Produce QQC records and appropriate user friendly reports to indicate potential for improving data quality. Provide the capability of replacing data under operational control. (MOSO) [D]

r) Deliver telemetry data.

When science and engineering (S&E) telemetry is received by the DSN, with a bit SNR (E_b/N_o) at input to symbol-synchronization of at least 4 dB, TMOD shall provide quality, continuity and latency for science packets delivered to the project database, such that, within 12 hours of data receipt, the delivered data contains, on average, no more than one packet gap or error, within 10,000 packets. The S&E telemetry stream is both Reed-Soloman and Convolutionally encoded. A MOC packet is about 10,000 bits in length. (DSN) [L]

s) Record telemetry data (DSN).

Keep a recording of mission critical telemetry data at the DSN stations for a period of 30 days after it is received. (Ref. MRD 4.3.3) (DSN) [D]

t) Receive telemetry data (MGDS)

MGDS shall accept and capture telemetry data from the DSN such that the rate of uncorrectable bit errors induced by MGDS processes shall not exceed 10^{-8}. The rate of packet loss induced by MGDS shall not exceed 0.5×10^{-4}. (Ref. MRD 8.3.7) (MOSO) [D]

u) Provide display capability of channelized telemetry data, including, but not limited to channel number, DN and EU values, channel names, channel types, ERT and SCLK. Provide X-Y graphing and tabulation and plot capabilities. Provide concise display of memory readout values and command verification. (MOSO) [D]

v) At least 3 different classes or levels of alarm indication shall be provided, selectable by the template designer for each particular situation. The different alarm types shall be visually easily distinguishable by different color indication. (MOSO) [L]

w) An audible tone generation capability shall be provided as an additional means of indicating the entering or exiting of an alarm condition.(MOSO) [L]

x) Accept a serial telemetry bit stream (10 bps - 83.5 Kbps) from the S/C via ground support equipment. (MOSO) [D]

4.5.3.2 Command

See Figure 4.5.3 Command Data Flow for a flow diagram of the GDS and MOS processes that lead to transmission of commands to the spacecraft. The key input to the Command Subsystem is the SCMF which is produced by PSS as described in section 4.2. The MGS Command Process is controlled by the MOS as described in Volume 3, Section 2.1.2. Some important features are 1) strong empowerment of the investigators to control their instruments through Non-interactive Payload Commands, 2) rigorous, *a priori* demonstration of interactive command efficacy and safety through software modelling, testbedding, and flight team review, and 3) oversight of the whole uplink process is supported by an Automated Command **Tracker** (ACT) which identifies, links, and records the necessary information at greatly reduced logistical cost. See Figure 4.5.4 for a data flow diagram of the ACT.

The Command Subsystem requirements are listed below.

a) Provide formatting of command data as documented in module CMD-4-6 of JPL Document 820-13 (the same as SFOC-1-CMD-DSN-Cmdmsg), and transmission to a tracking station for subsequent radiation of commands to the MGS spacecraft. (reformatting from SCMF to GCMD) (MOSO) [L]

b) Provide command standards, limits and warning/abort limits information to the DSN. (MOSO) [L]

c) Provide acknowledgement of receipt at the DSN and display content of GCMD command data sequences sent to the tracking station. (DSN, MOSO) [L]

d) Provide confirmation when the commands were correctly radiated to the MGS spacecraft by the tracking station. (DSN) [L]

e) Display and store command confirmations.[(MOSO) L]

    1) Provide a display(s) to confirm that commands were correctly radiated to the MGS S/C by the tracking station.

    2) Store confirmation that cmds were correctly radiated

f) Provide displays of key command data, such as generated commands, status data, and control messages to the Multi-Mission Control Team and the DSN Ops Team (Real Time subsystem only). (MOSO, DSN) [L]

g) Produce and maintain a command data base (containing command mnemonics, operational codes, parameters, data fields, and rules) for use by the Planning and Sequence Subsystem. (MOSO, PSS) [D]

h) Operate with batch executive software produced by PSS and MOS.

i) Automatically track all commands from electronic request through final disposition as shown in dataflow diagram Figure 4.5.4. (MOSO) [L]

j) Decompose an SCMF and generate a corresponding serial command bitstream (7.8125 - 500 bps) to the S/C via ground support equipment. (MOSO) [D]

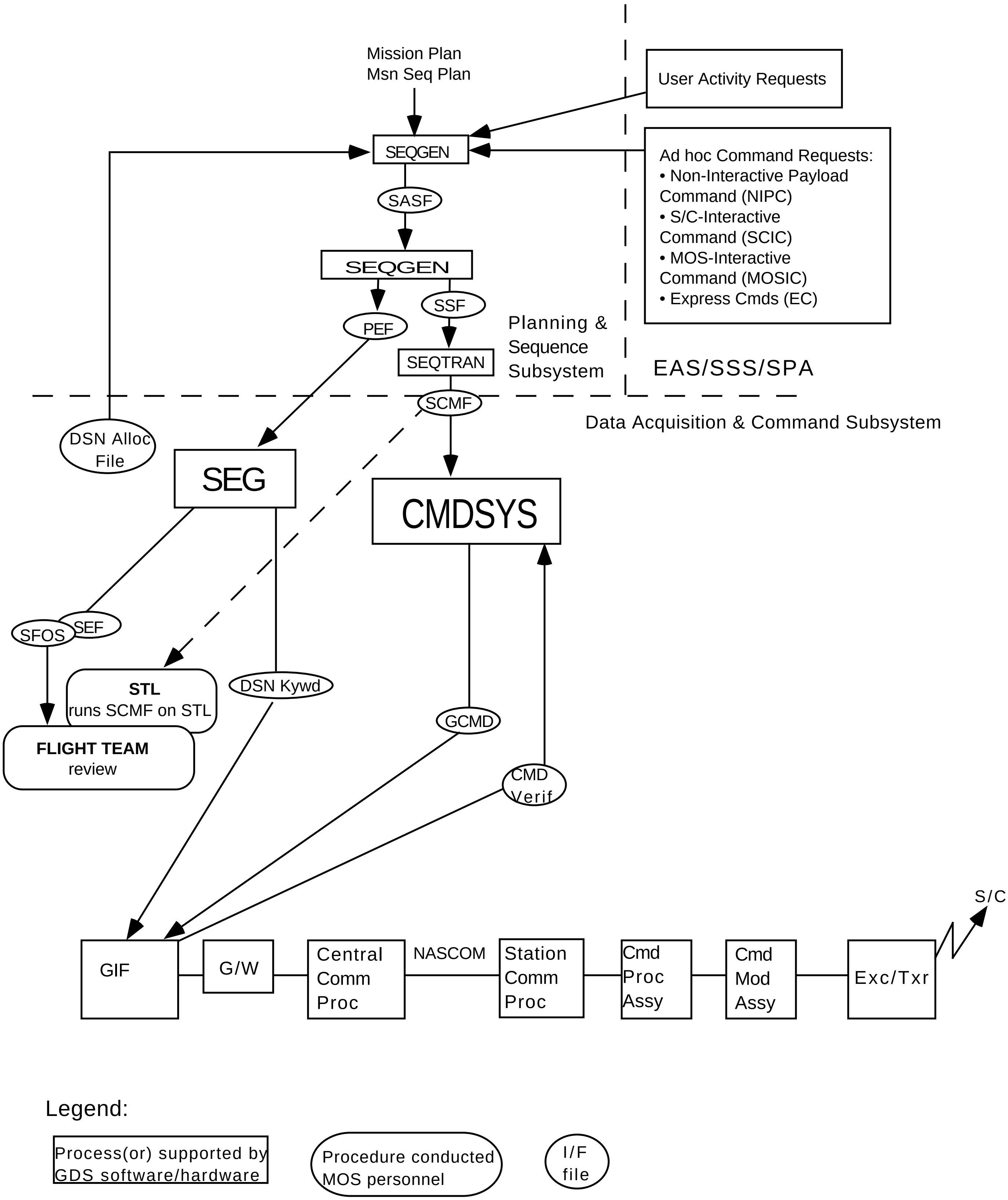

Figure 4.5.3 Command Data Flow

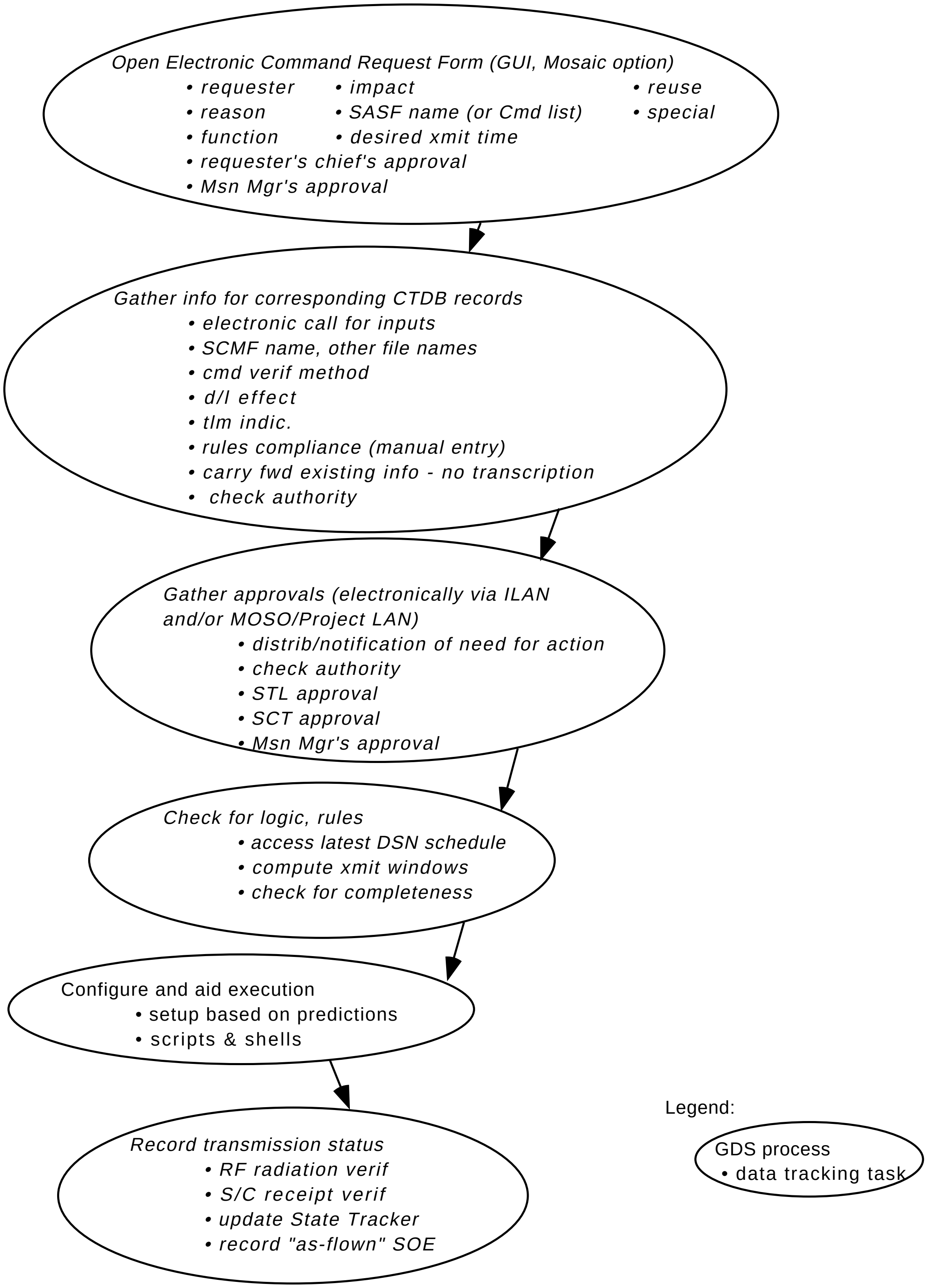

Figure 4.5.4 Automated Command Toolkit (ACT) Data Flow Diagram

4.5.3.3 Monitor

a) Generate DSN Monitor data blocks in accordance with the **MON 5-15 or -19** module of document 820-13. The blocks will contain station status, configuration, and performance information for use by the Project. The blocks will be transmitted on 5-second intervals. (DSN) [L]

b) Extract, channelize and display on request DSN Monitor Data. Store all monitor data at the PDB. (MOSO) [L]

c) Generate displays of the GDS status to the Real Time Ops Team and the DSN Ops Team. (MOSO, DSN) [L]

d) Provide displays of status and configuration of MGDS subsystems, which pertain to critical stream data flow, including identification of users and processes. (MOSO) [L]

e) Provide display capability for a selected number of records of real time monitor data. (MOSO) [L]

f) Provide display of doppler pseudo-residuals from DSN to NAS. (DSN, MOSO) [L]

4.5.3.4 Simulation

a) Support Simulation Activities.

Support short-loop and DSN stand-alone simulation activities. This includes the capability to provide command responses and generate monitor data for short-loop sim [L], being able to generate simulated data at the DSS for simpler stand-alone DSN simulations and being able to accept recordeded data at the DSS for more realistic stand-alone DSN simulations. (MOSO) (DSN) [D]

b) Generate simulated mission data.

MOSO shall be able to simulate, from internal data storage and tapes of MGDS captured and Spacecraft Checkout Station (SCS) generated telemetry, the modes and data rates that the spacecraft shall produce during the mission [D]. MOSO shall also be able to generate simulated DSN Monitor and MGS command responses for use by the MGS Project for test and training. (MOSO) [L]

c) Support Simulation Data Interfaces

Support DSN stand alone simulation data interface (in conjunction with MGDS SIM) for the purpose of testing the Ground Data System (GDS) hardware and software and to train operations personnel.(DSN) [D]

d) Generate simulated telemetry data

Generate simulated telemetry data streams for spacecraft data rates. This capability shall be used for stand-alone simulation as well as internal testing. (DSN) [D]

e) Generate simulated monitor data

Generate station monitor blocks to simulate a normal Mars Global Surveyor station pass. The blocks will comply with the format documented in module **MON 5-15 or -19** of document 820-13 and will be generated on 5 second intervals.(MOSO) [L]

f) Generate simulated tracking data

Generate station tracking data blocks to simulate a normal Mars Global Surveyor station pass. Tracking data includes ranging and doppler data, and ODFs and ATDFs. The data contained in these "simulated" blocks will be a static representative of doppler values. (DSN) [L]

g) Accept, store, and replay captured tlm.

Provide a streamlined mechanism for formatting and delivery to the DSN Tlm Simulation Assembly (TSA) of MGDS captured tlm. Replay stored data from the TSA. (MOSO/DSN - TMOD) [D]

h) Generate simulated radio science data. Generate simulated static radio science data derived from a test data source such as test translator or test transmitter. (DSN)[L]

i) Generate and transmit simulated telemetry data for all spacecraft telemetry data rates. Provide the capability for the DSN to support a DSN stand-alone simulation data interface. (MOSO) [D]

j) SIM shall accept operator inputs to control simulated MGS standard telemetry packet formats [D], DSN monitor formats and Project command responses. (MOSO) [L]

k) SIM shall accept operator controls to edit simulated data streams or formats and to specify the input and output data streams. (MOSO) [D]

l) SIM shall be able to corrupt any data according to the position within the transfer frame or packet. (MOSO) [D]

m) SIM shall be able to create data with specific values by channel position using an MGS supplied decom map, [D]; and according to channel ID. [L] (MOSO)

n) SIM shall encode two output telemetry streams with Reed-Solomon encoding using Berlekamp representation. (MOSO) [L]

o) The SIM software shall simulate DSN station hand overs. (MOSO) [L]

p) SIM shall produce 2 simultaneous monitor functions. (MOSO) [L]

q) SIM shall be able to write any simulated telemetry data to storage. (MOSO) [D]

r) SIM shall produce status, performance and error-logging reports. (MOSO) [D]

s) The SIM software shall produce status, performance and error reports. Error reports shall include errors that resulted from the simulation process. (MOSO) [D]

4.5.3.5 Tracking and Radio Science

a) Measure downlink carrier Doppler (in either a noncoherent mode or coherent mode) and spacecraft range. Also, provide supplementary data concerning the DSN equipment such as system noise temperature and tracking elevation angle. (DSN, MOSO) [L]

d) Generate Doppler and range predictions and compute residuals from actual Doppler and range measurements. Residuals shall be available in the PDB in real time or very near real time and the capability to display this data shall be provided. (DSN, MOSO) [L]

c) Deliver to the PDB measurements of the local weather at the DSN tracking station, and estimates of the total electron content of the earth's ionosphere along the radio beam's ray path. (DSN, MOSO) [L]

d) Calculate media calibrations to correct the Doppler and range measurements for the effects from the Earth's troposphere and ionosphere and deliver these to the PDB. (DSN, MOSO) [L]

e) Deliver to the PDB a Timing and Polar Motion File containing best estimates of past and future Earth rotation and polar motion. (DSN, MOSO) [L]

f) Acquire radio science open-loop receiver data and deliver them to the PDB. (DSN, MOSO) [L]

g) Generate RS Performance data

Generate status, configuration, and performance (SCP) data, including Signal Spectral Indicator (SSI)**,** of the DSN equipment involved in the acquisition of closed-loop Doppler, range, and radio science open-loop receiver data. (DSN) [E]

h) Extract, channelize and display on request DSN RS SCP, including Signal Spectral Indicator (SSI), Data. Store all RS SCP data at the PDB. (MOSO) [E]

i) Deliver to the Mars Global Surveyor Radio Science Support Team a copy of the predicts used to tune the radio science open-loop receivers and start and stop time of radio science open-loop data collection. (DSN) [L]

j) Provide DSN station locations and error covariances. (DSN) [L]

k) Provide DSN station range delays in the PDB. (DSN, MOSO) [L]

l) Provide the spacecraft range delay. (DSN, MOSO) [L]

Tracking and Radio Science Output Requirements

The following data products are required. See Figure 4.5.5 Radiometric Data Flow and Figure 4.5.6 RS Open-loop Data Flow.

m) Orbit Data Files (ODF) in SFDU format containing Doppler and range measurements and ancillary data (e.g., AGC, tracking angles, station and spacecraft delays, etc.). This product shall be delivered to the PDB. (TRK 2-18)

n) ASCII ODF containing Doppler and range measurements and ancillary data (e.g., AGC, tracking angles, station and spacecraft delays, etc.). This product shall be delivered to the NAV Computer. (TRK 2-28)

o) Archival Tracking Data Files (ATDF) in SFDU format containing Doppler and spacecraft range measurements and ancillary data (e.g., system noise temperature, AGC, tracking angles, station and spacecraft range delays). (TRK 2-25)

p) Measurements of the local weather at the DSN tracking stations (including near surface temperature, pressure, and dew point) and estimates of the total electron content of the Earth's ionosphere along the path of the radio signal from the DSN station to the MGS spacecraft. (TRK 2-24)

q) Doppler and Range corrections for calibrating for the Earth's troposphere and ionosphere. (TRK 2-23)

r) Timing and Polar Motion File. (TRK 2-21)

s) deleted (was open-loop receiver tuning predictions)

t) Open-loop receiver data. (RSC 11-11)

u) Data needed to monitor the status, configuration, and performance (SCP) of the DSN equipment involved in the acquisition of closed-loop Doppler, range, and radio science open-loop data. (**MON 5-15 or -19**, RSC 11-12)

v) Doppler and range residuals. (**MON 5-15 or -19**)

w) DSN station locations and error covariances.

4.5.3.6 Mission Control and Data Management

a) Generate standard sequence review products.

b) Generate DSN keywords for transmittal to the DSN.

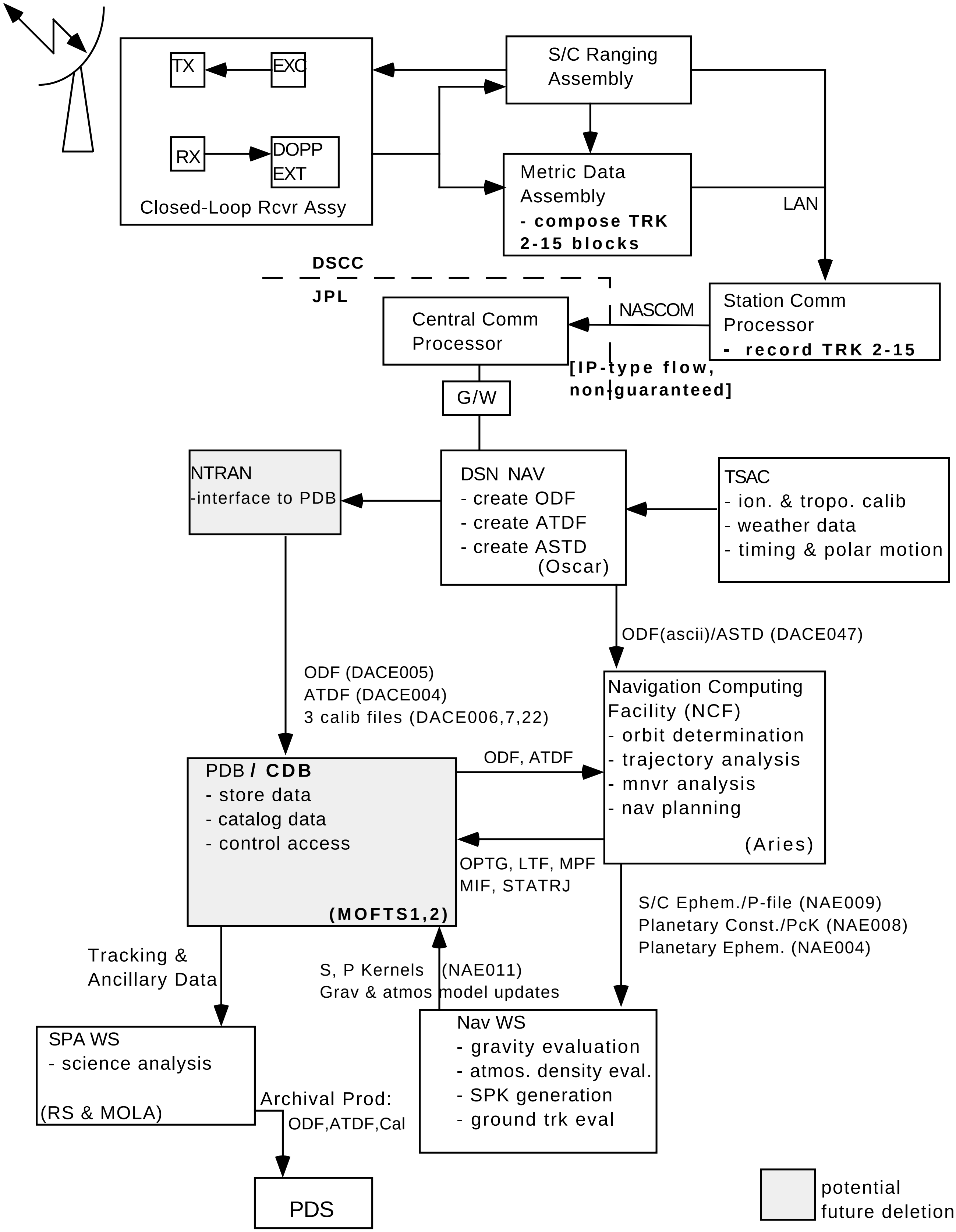

Figure 4.5.5 Radiometric Data Flow

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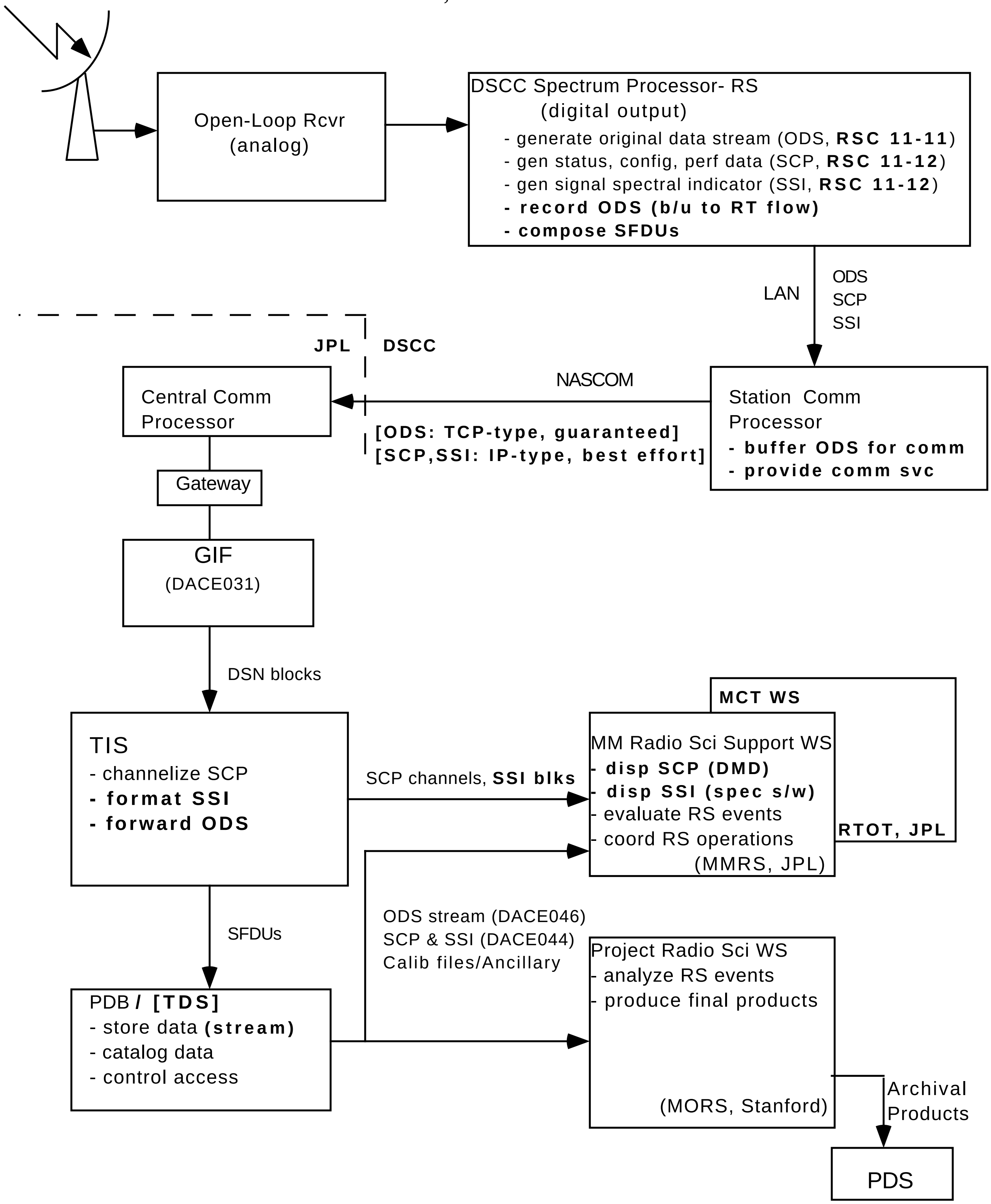

Figure 4.5.6 Radio Science Open Loop Data Flow

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4.5.4 DAC Performance Requirements

The following are performance requirements on the Data Acquisition and Command Subsystem. Except as indicated, all DAC performance requirements are needed at phase [L]:

a) All raw telemetry used for monitoring health, safety and performance of the spacecraft and/or Ground Data System shall be displayed (or otherwise made available for monitoring) within 5 minutes, from input to the DSN antenna to display output (MOSO, DSN). This also includes changes in performance and/or configuration changes within the DSS and/or MGDS. (DSN and MOSO)

b) Provide recovery of all time critical files within 5 minutes in the event of lost or damaged files.

   Time Critical Files:

   1) GCMD files intended for transmission within 24 hours

c) Capability to define and monitor 2500 spacecraft engineering channels for monitoring by the MMCT. (MOSO)

d) Configure DSN uplink capability, in the event of an emergency, within 5 minutes if a station is on track. (DSN)

e) Configure DSN uplink capability, in the event of an emergency, within 30 minutes if the DSN is not on track. (DSN)

f) Configure MOSO/MGDS command capability in the event of an emergency, within 5 minutes.

g) Acquire, process, display and store engineering data at real-time rates of 10 bps (emergency mode), 250 bps (mission mode) and 2 Kbps (engineering only mode). (DSN, MOSO) [D]

h) Acquire, process and store telemetry data streams of up to 85.3 Ksps, including up to 32 Kbps of engineering telemetry. (DSN, MOSO) [D]

i) Process and transmit Command data streams at rates of 7.8125 - 500 bps. (DSN, MOSO) [D]

j) After calibration, Doppler measurements shall be accurate to 0.6 mm/sec (3 sigma) when integrated for 60 seconds, except when the Sun-Earth-probe (SEP) angle is less than 15 degrees. The contribution to Doppler error from DSN equipment shall be less than 0.1 mm/sec (3 sigma) when integrated for 10 seconds.(DSN)

k) After calibration, spacecraft range measurements shall be accurate to 15 meters (3 sigma) when independent range measurements are made every 10 minutes, except when the SEP angle is less than 15 degrees. The contribution to range measurement noise from DSN equipment shall be less than 3 meters (3 sigma).(DSN)

l) All steps involved in acquiring radio science open-loop data at the DSN and transferring data to the PDB shall be reliable enough to ensure that 19 out of 20 (95%) occultation events that occur during tracking passes are delivered to the RS investigators with a bit error rate of less than 10^{-7}.

m) The spectral density <u>of either the phase or amplitude noise</u> due to all DSN equipment involved in radio science open-loop recordings shall be less than:

Frequency Offset from Carrier (Hz)	Phase Noise Spectral Density (single Sideband, dBc/Hz)
1	-53
10	**-70**
100	**-70**
1000	**-70**

n) During all occultation measurements pointing control of the DSN antennas shall be accurate enough to limit the resulting variations in the signal intensity to less than 0.1 dB. [E]

o) After calibration, the overall amplitude stability of all DSN equipment involved in radio science open-loop recording shall be less than 0.1 dB over 20 seconds during atmosphere occultation measurements.

p) Doppler and range corrections for the Earth's atmosphere shall be accurate enough to meet the data accuracy requirements stated above (requirement i and j of this section).

q) The DSN station locations provided to the MGS Project shall have at least the following 3 sigma accuracy. Absolute accuracy:

distance from the Earth's spin axis	1.0 meters
longitude	2.0 meters
distance from the Earth's equatorial plane	27 meters

Relative accuracy:

Station coordinates relative to other DSN stations shall be accurate to 30 cm (3 sigma). A complete error covariance matrix shall be provided.

r) Tracking and radio science data and ancillary information shall be provided in the PDB on the following schedule:

Radio science open-loop Data shall be delivered to the PDB nominally in realtime and no later than 5 minutes of the time the measurements are made at the DSN tracking station.

Weather data shall be delivered to the PDB within 1 week of the end of the tracking pass.

Doppler and range corrections shall be delivered to the PDB on the same schedule as Orbit Data Files.

Timing and Polar Motion Files shall be available for use with the applicable Orbit Data File.

Status, configuration and performance data shall be available to the project within one minutes of its generation at the DSN station.

Tracking data delivery requirements are contained in Section 3.6, "Data System Performance Requirements", item e).

4.5.5 Interface Requirements

See Table 4.5.1a DAC Interfaces - DAC Outputs and Table 4.5.1b DAC Interfaces - Inputs to DAC.

Table 4.5.1a DAC Interfaces - DAC Outputs

SIS #	INTERFACE/TYPE	RECEIVER
DACE001	DSN VIEWPERIOD FILE	EAS,NAS,PSS,(DSR)
DACE002	COMMAND DATABASE	DAC,(DSR),PSS,EAS
DACE003	DSN ALLOCATION FILE	NAS,PSS,(DSR)
DACE004	ARCHIVAL TRACKING DATA FILES (ATDF)	NAS,SPA,(DSR)
DACE005	ORBIT DATA FILES (ODF)	NAS,SPA,(DSR)
DACE006	MEDIA CALIBRATION DATA FILE	NAS,SPA,(DSR)
DACE007	TIMING AND POLAR MOTION FILE	NAS,SPA,(DSR)
DACE009	TRACKING STATION LOCATIONS AND ERR FILE	SPA,(DSR)
DACE011	RAW MONITOR BLOCKS	DAC,(DSR)
DACE012	CHANNELIZED ENG DATA	DAC,SSS,EAS,(DSR)
DACE013	CHANNELIZED MONITOR DATA	DAC,(DSR)
DACE014	TELECOM PERFORMANCE PREDICTIONS	EAS, (DSR)
DACE016	ENG AND MON CHANNEL PARAMETER TABLE	DAC,(DSR)
DACE017	ENG, MON AND QQC CCL-FILE	DAC,(DSR)
DACE020	DAILY DETAILED COMMAND REPORT	DAC
DACE022	METEOROLOGICAL WEATHER DATA	SPA,(DSR)
DACE023	DSN Sim Interface	DAC
DACE025	DSN FORMATTED COMMAND FILE	DAC,PSS,(DSR)
DACE029	ENG AND MON DECOM MAP	DAC
DACE031	DSN-MGDS Interface	DAC
DACE033	TRANSFER FRAME ANOMALY FILE [TBD]	DAC
DACE034	QQC RECORDS	DAC,PSS,EAS
DACE037	ECDR	DAC,EAS,(DSR)
DACE038	COMMAND VERIFICATION [TBD]	DAC
DACE040	ENGINEERING TELEMETRY PACKETS	DAC,EAS
DACE041	COMMAND ACKNOWLEDGEMENTS	DAC,EAS
DACE042	COMMAND TRANSLATION TABLE	PSS
DACE043	RAW TELEMETRY FRAMES	DAC
DACE044	RADIO SCIENCE OPEN LOOP SCP DATA	DAC,SPA,(DSR)
DACE045	RADIO SCI. OPEN LOOP SCP DATA DECOM MAP	DAC,(DSR)
DACE046	RADIO SCIENCE OPEN LOOP DATA	DAC,SPA,(DSR)
DACE047	ASCII S/C TRACKING DATA FILE	NAS
DACE048	Browser Configuration Files	SSS [EAS]
DACE049	DMD TDL File	SSS [EAS]

Table 4.5.1b DAC Interfaces - Inputs to DAC

SIS #	Interface	Producer
DSR017	Spacecraft Clock Coefficients File	DSR
LUE001	Launch Polynomials	LUE
LUE002	Injection Initial Conditions	LUE
NAE001	Station Polynomial File	NAS
NAE002	Light Time File	NAS
NAE004	Planet Ephemeris & Errors File	NAS
NAE009	Spacecraft Ephemeris File	NAS
PSE004	Spacecraft Command Message File	PSS
PSE003	Spaceflight Operations Schedule File	DAC
PSE005	DSN Keyword File	DAC

4.6 DATA STORAGE AND RETRIEVAL SUBSYSTEM

This section provides the functional requirements for and the high-level design of the Data Storage and Retrieval Subsystem (DSR) of the Mars Global Surveyor (MGS) Data System. This section includes a functional description of the DSR, a definition of required program sets and specifications for performance, internal interfaces, and test and traceability requirements as applicable to the DSR. It identifies the organization responsible for fulfilling each of the requirements, i.e. the Deep Space Network (DSN), Mission Operations Support Office (MOSO) or the MGS Project.

4.6.1 Introduction

The DSR subsystem of the MGS Data System accepts monitor, tracking, radio science, and spacecraft telemetry data from the DAC subsystem; DSR accepts MGS Project data products from other subsystems; DSR catalogs and stores these data in the Project Data Base until End-Of-Project (EOP) and provides access to authorized users. The DSR formats MGS Project raw data packets and ancillary data and forwards them to the Planetary Data System (PDS) for long-term archive.

The DSR is comprised of four components as depicted in Figure 4.6.1. They are the Data Transport component, the Project Data Base and E mail component, the Data Products component, and the User tools component.

4.6.2 DSR Functional Requirements

The functional requirements on the DSR are specified below. MOSO is responsible for providing the tools necessary to fulfill the DSR requirements.

a) Store and Catalog Data Products

Store and catalog MGS data products for subsequent access by other subsystems. The catalog capability shall be able to search and scan for specified data products by at least mission name, data set ID, MGDS product ID, data type, instrument ID, orbit number, and record creation time (RCT), PDB insertion time, ERT, SCET and SCLK). (MOSO) [D]

b) Provide Security for PDB data products

Provide physical and electronic security for data products in the PDB. This includes ensuring the integrity of the data **and proper authority and authenticity for user access**. (MOSO)[L]

c) Provide Access to Data Products

Provide access to data products in the Project Data Base for which a user is authorized [D]. Restrict access to those data products for which a user is not authorized. (MOSO)[L]

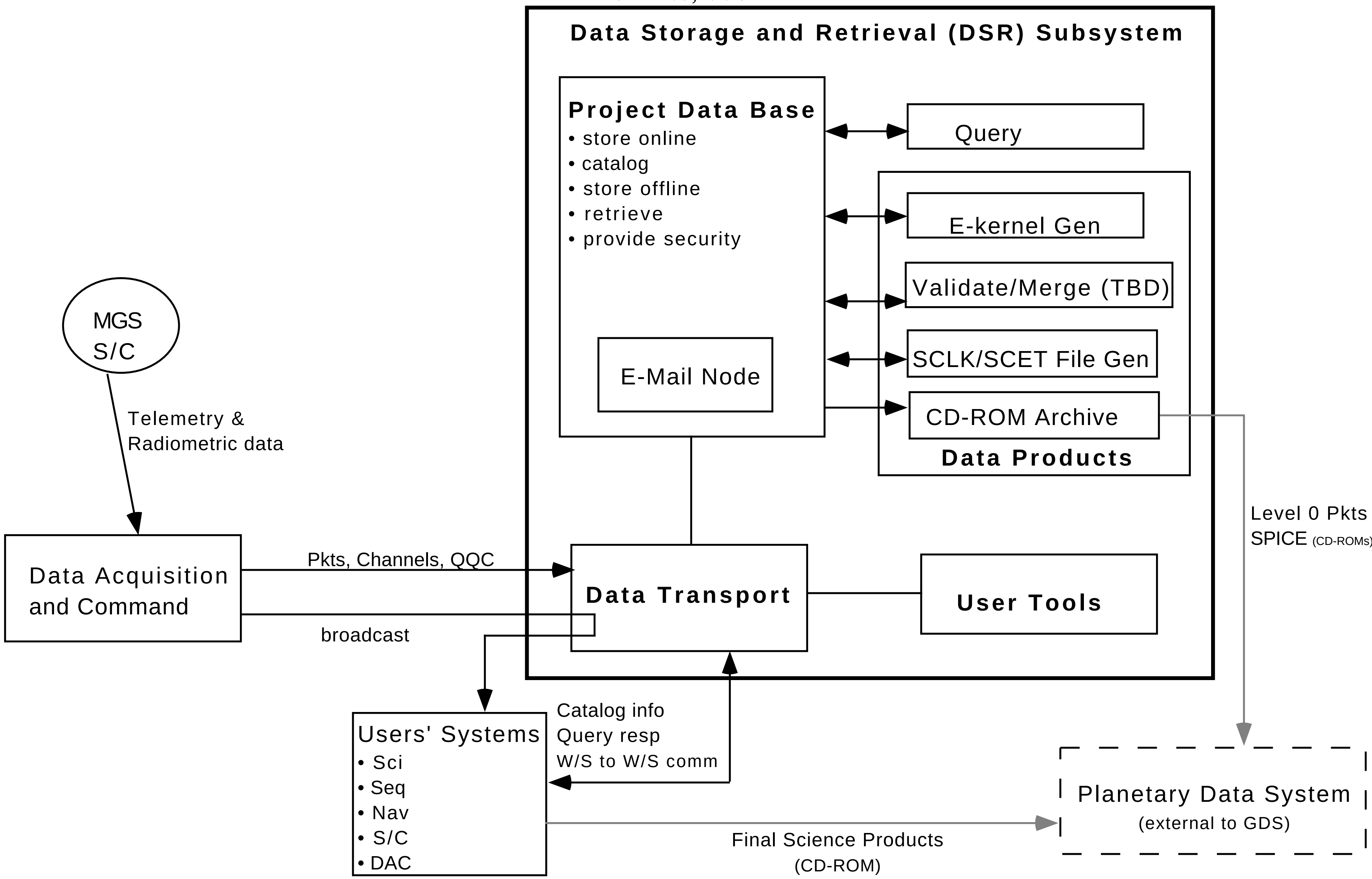

Figure 4.6.1 Data Storage and Retrieval Functional Block Diagram

12/12/94

d) Transport Data to and from the PDB

Transport data electronically from the EAS, PSS, DAC, PSS and the NAS workstations to the Project Data Base (PDB) and from the PDB to the EAS, PSS, DAC, PSS and the NAS workstations. (MOSO)[D]

e) Transport Data Between Workstations

Transport data electronically between workstations. (MOSO)[D]

f) Transport file data between the PDB and the Navigation Computing Facility (NCF) and NOCC nodes. (MOSO)

g) Support CD-ROM generation for data transfer to the PDS (MOSO)[L]

h) Transfer Data via transportable media

Transport data via transportable media between the PDB and the SOPC workstations. (MOSO)[L]

i) Generate E kernel (MOSO)[L]

j) Provide E mail capability

Provide an E mail node that will store and transfer messages between users of the GDS. (MOSO)[L]

k) Generate Spacecraft Clock Correlation File (MOSO)[L]

l) Provide software tools which perform SFDU creation and removal. (MOSO)[D]

m) Text Processing Capabilities

The MOSO shall provide basic text editing capabilities that will allow creation of and changes to the inputs to the E kernels and E-mail. (MOSO)[D]

n) The MGS GDS User Interface Software Shall Have a Common Look and Feel (MOSO)[L]

o) The operations of and the capabilities provided by each screen of the MGS GDS User Interface software shall be apparent to a user who is generally familiar with the interface. (MOSO) [L]

p) Provide hardware to meet DSR MOSO requirements

Provide for a hardware configuration and provide the necessary hardware to meet the functional requirements levied on the MOSO and the Project in section 4.6 of MOS Vol. II. (MOSO)

q) Provide Offline Storage

Provide an offline storage capability for stream and file data; include information regarding offline data in the online catalogs. (MOSO) [L]

4.6.3 Functional Design

The functional diagram of the DSR is shown in Figure 4.6.1. The DSR accepts data from the DAC and other GDS subsystems and is responsible to store, process, validate and control access to that data. The components of the DSR include: Data Transport, Project Data Base, Data Products, and User tools. The physical incarnation, i.e., DSR's processors and communications links, is largely inherited from Mars Observer and is shown in Figure 4.6.2

4.6.3.1 Data Transport

The Data Transport component receives data from DAC and provides for storage and cataloging in the Project Data Base (PDB). Data Transport uses both standard protocols and MOSO-unique tools to move data products between the subsystems and the PDB and to move data between the subsystems of the GDS.

4.6.3.2 Project Data Base

The second component of the DSR, the PDB, catalogs and stores telemetry and ancillary data and data products from project operations. Data may be accessed by any authorized user. Users (or user applications) initiate the data transfer process. Data will be retained until the end of the project. The PDB component is functionally divided into three subcomponents: online, offline and E-mail.

All data is initially stored in the online database, but will be moved off-line per operations procedures. Retrieval of data from the offline subcomponent may require operator intervention. The PDB catalog will provide online/offline status.

The E-mail node is a separate subfunction of the PDB which stores and transfers messages between users. The E-mail node is governed by a set of rules which are different from the other two subcomponents of the PDB. It operates 24 hours a day and has reliability similar to the other two subcomponents, but users will be allowed to delete data stored on the E-mail node. Deletions cannot be done on the other two subcomponents. E-mail may be used for creation of project data, but all official project data must eventually be loaded into the online subcomponent of the PDB by the Data Administration Team.

4.6.3.3 Data Product

The third component, Data Products (DP) contains the software and hardware necessary to produce three MGS data products: the E kernel, data validation, and the spacecraft Clock Coefficients File.

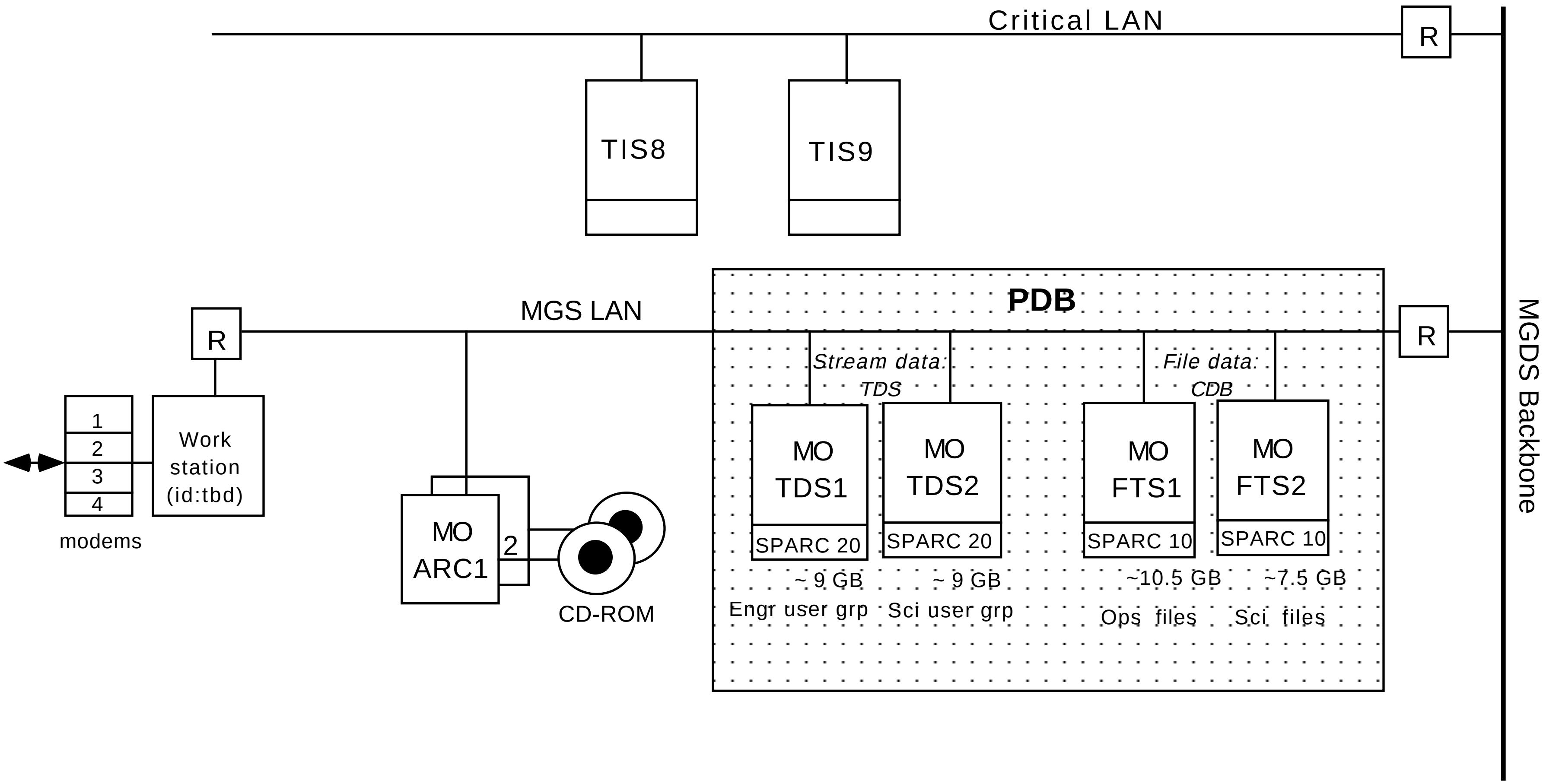

Figure 4.6.2 MGS Project Data Base Configuration

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4.6.3.3.1 SPICE E kernel

The E kernel shall be produced with software provided by MOSO.

The E kernel contains a time-tagged and time-ordered listing of events and other data that are significant to the knowledge of how the instruments were operated and why certain observations were made, particularly when Investigators made coordinated sequences of observations. This includes information regarding the events that affect an instrument, the spacecraft, or the MGS GDS.

The inputs to this kernel shall be from the instrument teams, operations teams and the DP component. The DP component shall acquire inputs from the instrument teams and generate the E kernel with software provided by NAIF.

4.6.3.3.2 Validate, Recall and Merge

The Validate, Recall and Merge (VRM) process consists of validating the telemetry and monitor data and the recall and merge of data necessary to meet the Project's quality, quantity, and continuity (QQC) standards.

4.6.3.3.3 Spacecraft Clock Coefficients File Generation

The Spacecraft Clock Coefficients File is generated from inputs received from engineering data and navigation data. This file shall contain the relationship between Earth Receive Time (ERT), Spacecraft Clock Time (SCLK) and Spacecraft Event Time (SCET).

4.6.3.4 User Tools

The User tools component is composed of the software necessary to create, edit and/or strip SFDU labels, edit text, generate reports, perform E-mail to PDB file conversion, and other functions needed by users of the DSR. The NAIF toolkit is included in this component.

4.6.4 Program Set Requirements

The software requirements on the components of DSR are defined in the following sections. MOSO shall be responsible for creating and maintaining the software necessary to meet these requirements. Deliveries of this software shall be tested and approved by the MGS Project before being used operationally.

4.6.4.1 Data Transport Software Requirements

The data transport requirements are:

a) Transport data electronically from the online and offline subcomponents of the PDB to the DAC, EAS, PSS, DSR, SSS and NAS (including NCF) subsystems and from the Subsystems to the PDB. (MOSO)[D]

b) Transport electronic mail between the MGS GDS Subsystem workstations and the mail node. The mail node must interface with the User tools component such that mail may be edited, SFDU formatted, and stored on the PDB. The mail node is designed to be in operation 24 hours a day. (MOSO)[L]

c) Transport data from the PDB to the PDS. Data sent to the PDS will be made compatible with PDS format and SFDU requirements prior to this transfer. (MOSO)[L]

d) Store in the PDB at least 99.95% of all downlink data received by MGDS Acquisition (ref. 542-400, MRD section 4.3.7). (MOSO)[L]

e) Exclude science fill packets from the PDB. (MOSO)[L]

4.6.4.2 Project Data Base Requirements

The Project Data base has two distinct and independent components. The Telemetry Delivery System (TDS) processes the stream-type data. The Central Data Base (CDB) manages the file-type data. See Table 4.6.1 for the overall PDB storage requirements. (MOSO)

4.6.4.2.1 Loading PDB Data

The PDB shall accept new data objects, both streams and files, as follows

a) The **TDS** shall be able to accept, catalog and store all properly formatted QQC, engineering, science (including RS), monitor and radiometric data. [L]

b) The PDB shall produce a backup copy of any data product within 24 hours of the time the data is written to the PDB. [L]

c) The PDB shall be capable of accepting and retrieving binary data that is in SFDU format. Software loaded in the PDB shall be treated as a data product, i.e., the PDB shall not be required to run the software, such as the NAIF toolkit. [L]

d) The PDB shall accept data via a transportable media that is compatible with the SOPC capabilities. [L]

e) The PDB shall have the ability to accept data from remote MGDS workstations. [E]

f) The PDB shall accept data via the MGS LAN. **[L]**

g) The PDB shall accept data from all GDS Subsystems as outlined in Appendix A and as specified in the MOS Volume V - Interfaces. **[L]**

Table 4.6.1 PDB Storage Requirements (E)

DATA TYPE	Data Storage[1] (GBytes) Daily Throughput	Total Online	Days Online	Offline
Stream Data:				
Downlink Data				
Engr Telemetry	0.01	0.5	50	6.0
Derived Engr Data	0.02	1.0	50	12.0
RM, RS	0.05	2.5	50	30.0
Science Telemetry	0.12	2.7	22	84.0
Monitor	TBD			
File Data:				
Uplink Data	0.05	1.0	20	30.0
Analysis Data (inc. Sci SPDP, 0.1 GB)	0.10	4.0	40	65.0
Ops Data	0.05	2.0	40	30.0
Catalog	----	0.1	-----	
Total Estimate (Approx.)	0.40	13.8		257.0
10 Percent Reserve (SFDU's, etc.)	0.04	1.4		26.0
Grand Total	0.44	15.2		283.0

E Mail Node Storage Requirements

	(GBytes)
E mail	0.15

Note: [1] Requirements do not include space for PDB operating software.

h) The **CDB** shall reject an incoming ancillary data product if it is completely redundant (in terms of catalog information) with a data product that has already successfully been loaded. An error message shall be sent which informs the user of the rejection. [L]

i) The **CDB** shall store all delivered data **on-line. [L]**

The TDS shall store all delivered data on-line until it is deleted by the project database administrator. [L]

j) If the PDB can not load data correctly an error message shall be sent to the user who attempted to unsuccessfully load an ancillary file. An error message shall be sent to a system operator if telemetry data is unloadable. [L]

k) PDB file headers should be detected, a loading decision made, and the action reported to the submitter without requiring that the entire file be loaded first. [L]

l) The PDB shall provide a utility for workstation users to submit data to and request and receive data from the PDB. **[L]**

m) All computers which are part of the MGS GDS shall be able to load data into, and retrieve data from, the PDB without requiring the intervention of an operator. [L]

n) The CDB shall accept spacecraft documentation as outlined in Table 4.6.2 for operational use. [L]

4.6.4.2.2 Cataloging PDB Data

The PDB shall account for all included data objects as follows:

a) The PDB software shall create and maintain a catalog capable of indexing/identifying data items. All data products in the PDB shall be cataloged.[L]

b) The PDB shall have the capability to add new keywords to a file label during the project. [L]

File Data Attributes (keywords) created by the system include:

PDB insertion time
file size
location of file (logical/physical address)
Record Creation Time (RCT)
online (or offline) status
if offline, then type of storage medium

Table 4.6-2 MGS Electronic Dictionary Documents

Dictionary	Author	Location	Format	Time Availability	User	File Custodian
Telemetry 542-SE-012	O. Short	Master-SCT Mac	Text: Word	Dev & Ops	author	author
			DB: FoxPro	Dev & Ops	author	author
		Copy-Col Srvr	*Text: Word*	*6/95 - L+30d*	*devel-*	*SCT*
			DB: FoxPro	*6/95 - L+30d*	*opers*	*SCT*
		Copy-PDB	Text: Word	L1.0 onward	Flt Tm	SA
			DB: FoxPro	L1.0 onward	Flt Tm	SA
		Copy-PDB	DB: ascii	L1.0 onward	Flt Tm	SA
		Copy-PDB	DB: CSV	L1.0 onward	Flt Tm	SA
Tlm decom map	O. Short	Copy-PDB	DACE029	L1.0 onward	Flt Tm	SA
Tlm CPT	O. Short	Copy-PDB	DACE016	L1.0 onward	Flt Tm	SA
Tlm CCL	O. Short	Copy-PDB	DACE017	L1.0 onward	Flt Tm	SA
Payload Tlm & Cmd, 542-303 [separate document]	C Kloss	Master - Olympus	Word	9/95 - L+30	author & devel.	Doc.
		Copy - PDB	Word	L1.0 onward	Flt Tm	SA
Command 542-SE-012	O. Short	Master-SCT Mac	Text: Word	Dev & Ops	author	author
			DB: FoxPro	Dev & Ops	author	author
		Copy-Col Srvr	*Text: Word*	*6/95 - L+30d*	*devel-*	*SCT*
			DB: FoxPro	*6/95 - L+30d*	*opers*	*SCT*
		Copy-PDB	Text: Word	L1.0 onward	Flt Tm	SA
			DB: FoxPro	L1.0 onward	Flt Tm	SA
		Copy-PDB	DB: ascii	L1.0 onward	Flt Tm	SA
		Copy-PDB	DB: CSV	L1.0 onward	Flt Tm	SA

Table 4.6-2 MGS Electronic Dictionary Documents (continued)

Dictionary	Author	Location	Format	Time Availability	User	File Custodian
Flight Rules 542-SE-013	J Neuman	Master-SCT Mac	Text: Word DB: FoxPro	Dev & Ops Dev & Ops	author author	author author
		Copy-Col Srvr	*Text: Word* *DB: FoxPro*	*6/95 - L+30d* *6/95 - L+30d*	*devel-opers*	*SCT* *SCT*
		Copy-PDB	Text: Word DB: FoxPro	L1.0 onward L1.0 onward	Flt Tm Flt Tm	SA SA
		Copy-PDB	DB: ascii	L1.0 onward	Flt Tm	SA
		Copy-PDB	DB: CSV	L1.0 onward	Flt Tm	SA
Payload Flt Rules, 542-302 incorp. in s/c rules	J Neuman (support by C Kloss)	Master-SCT Mac	Word	8/95 onward [-013 update]	author	author
		Copy - PDB	inc. in SE-013 [Word & ascii]	L1.0 onward	Flt Tm	SA
Block 542-SE-009	J Neuman	Master-SCT Mac	Text: Word	Dev & Ops	author	SCT
		Copy-Col Srvr	*Text: Word*	*6/95 - L+30d*	*devel-opers*	*SCT*
		Copy-PDB	Text: Word	L1.0 onward	Flt Tm	SA

Notes: Col Srvr = MMTI and JPL Collaborative Servers - not Mission System components
Doc = Project Documentarian
CM = Project Configuration Manager
Flt Tm = any authorized Flight Team member

c) The PDB shall provide a mechanism to allow an authorized user to mark data stored in the PDB as invalid. [L]

d) PDB shall prohibit file deletion except by authorized Data Administration personnel.

e) The PDB shall prohibit deletion of catalog entries except by authorized data administration personnel.

f) The PDB shall process catalog queries containing any logical combination of the relational operators equal, greater-than, less-than, and not, on all data attribute values. [**L**]

g) The PDB catalog shall be maintained online and accessible until EOP except during specific approved administrative activities). [L]

h) Activity in the PDB catalog shall be logged to an activity file in realtime. [L]

i) In the event of a catalog failure, it shall be possible to recreate the catalog to within less than 10 minutes of the most recent activity lost, by using the PDB Activity Log file. [L]

j) The PDB shall provide a mechanism to capture the results of a catalog search for subsequent processing. [L]

k) The PDB shall provide a mechanism to report to any authorized user all cataloged information regarding a specified data product. [**L**]

4.6.4.2.3 PDB Catalog Query

The PDB shall support catalog searches, data identification, and user response as follows:

a) The PDB shall be capable of servicing 90 concurrent catalog queries. [**L**]

b) The PDB catalog query shall allow data to be selected based on any attribute, or combination of attributes, defined for that data product.[**L**]

c) The PDB shall provide a user capability to query the catalog by an iterative narrowing of the search space. [L]

d) The PDB shall respond to queries by providing a user-specified subset of catalog information regarding applicable data products. [**L**]

e) The PDB shall allow any data having a SCLK time attribute to be queried by SCLK, SCET, ERT [L] or Orbit Number. [L]

f) The PDB shall use the most current available clock correlations when performing time reference conversions. [L]

g) The PDB shall always return a response to a catalog query. [**L**]

h) The PDB shall always return a "task finished" signal to the caller to indicate that a query has been accomplished, or has failed. [**L**]

i) The PDB catalog query protocol shall include an option that presents to the user the volume of data selected prior to retrieving file data. [L]

j) The PDB query protocol shall include an option that presents to the user an estimate of the volume of data selected, prior to retrieving telemetry data. [L]

k) The PDB catalog query function shall provide a command line interface for catalog queries [L].

l) The PDB catalog query function shall not preclude users from developing procedures for time-delayed retrievals. [E]

m) While a query is in progress, the user shall be apprised of the status of the query. [L]

n) The query capability shall provide a mechanism to cancel any query in progress. [L]

o) The catalog shall support the following types of attributes in addition to those listed in 4.6.4.2.2 b):
   integer
   floating point
   date
   time
   MO SCLK
   text string [L]

p) The catalog search shall support the following logical and operational parameters for specification of selection criteria: =, >, <, >=, <=, AND, OR, NOT, substring. [L]

q) The catalog user shall have the capability to display Catalog search results or capture for subsequent processing search results. [L]

r) The PDB shall enable a user to transfer more than one data product stored on the PDB as a response to a single request. [L]

s) The PDB shall contain a HELP feature that aids the user in querying the catalog and accessing data. [L]

t) The PDB's HELP feature shall be sensitive to the PDB function the user is currently using. [L]

u) The PDB shall provide to authorized users a system-level interactive query capability to access the PDB (such as SQL). [L]

4.6.4.2.4 PDB Stream Data Query

The PDB - Telemtry Delivery System shall support stream data queries as follows:

a) The TDS shall be able to retrieve telemetry packets and channelized engineering data. [L]

b) The TDS shall be able to retrieve tracking data, DSN monitor, and Radio Science data. [L]

c) Channel queries may be keyed on one or more of the following parameters: channel name, channel value, packet type and start and end time.

d) The telemetry retrieval tool shall not deliver redundant data to a user as a result of a single query. [L]

e) While a query is in progress, the user shall be apprised of the status of the query. [L]

f) The query capability shall provide a mechanism to cancel any query in progress. [L]

4.6.4.2.5 PDB File Retrieval

The PDB shall support file retrieval in response to a catalog query as follows:

a) The PDB shall allow file data to be retrieved only after the loading process for those data products is complete. [L]

4.6.4.2.6 Data Access

User access to the PDB shall be restricted as follows:

a) The PDB shall allow an authorized data administrator to define access privileges for each PDB user. [L]

b) The PDB shall provide a secure mechanism to authenticate users prior to providing any other PDB services. [L]

c) The PDB shall provide a mechanism to ensure that data products restored from secondary storage are reinstalled with user privileges consistent with the current database configuration. [L]

d) In the event of a refusal of service due to incorrect privileges a descriptive error message shall be returned to the user or calling process. [L]

e) An authorized user shall be able to access only that data and the portions of the catalog for which the user is granted access. [L]

f) The PDB shall allow an authorized data administrator to set read and write privilege defaults that will be applied to data types when they are loaded. [L]

g) The PDB shall allow an authorized data administrator to designate, at any time while the data product resides on the PDB, which users may read the data product or which users may write to the data product file. [L]

4.6.4.2.7 Data Base Administration

a) The PDB shall enable operations personnel to create, store and maintain access control data to all MGS data products that are loaded into the PDB until EOP. [L]

b) The PDB shall move MGS data products from primary (online) to secondary storage (offline) in the PDB when requested by an authorized data administrator. [L]

c) The PDB shall enable an operator to restore data from any PDB secondary storage source to accessible primary storage. [L]

d) The PDB shall provide the ability to create and maintain a completely redundant copy of the data that resides in the PDB. [L]

e) The PDB software shall allow the operator to request a storage utilization report of the online disk space, over which the operator has options for the type of display (i.e. object type or data owner). [L]

f) The PDB shall produce tabular displays of the disk space that a requested set of data products occupy. [L]

g) The PDB shall provide a mechanism, i.e., CD-ROM production, to deliver data products to the PDS on a regular basis as specified by operations procedures and the Project Data Management Plan. [L]

h) The PDB shall support the notion of location independence such that a user need not know where data (or the catalog) are physically stored. **[L]**

i) The PDB shall provide a mechanism to allow authorized users, or groups of users to invalidate (mark invalid, but not delete) a specific data product stored in the PDB. **[L]**

4.6.4.2.8 Monitor and Control PDB Operations

a) The PDB shall provide a mechanism to allow all data base administration (DBA) functions to be performed at a DBA workstation. [L]

b) A capability shall be provided to allow an operator to terminate any job. [L]

c) A capability shall be provided to monitor the use of system resources. [L]

d) All PDB processes shall generate explanatory error and warning messages in response to anomalies in performing their tasks. Such messages should also explain any automatic corrective action taken by the process. **[L]**

e) All PDB processes shall log all error and warning messages to a specified log file. **[L]**

f) The PDB shall avoid repetitive positive status messages. (An exception to this requirement is the "query-in-progress" message reported to users waiting for a query to complete.) [L]

g) The PDB shall support a checkpointing capability that automatically restores the database to a consistent state after a power failure, or other unexpected shutdown. [L]

h) The PDB shall prevent any data set from being deleted while in use. **[L]**

i) The PDB shall provide tools to ascertain in realtime the number of active queries, stream and file, and display key information regarding each active query. This shall be available to end users as well as DBAs. A capability to periodically sample and log this information shall be available to the DBAs.

4.6.4.2.9 Transport and Format of Data

a) The user shall initiate the data transfer process. [D]

b) The PDB shall be able to download data to computer compatible tape for mass transfer of data. **[L]**

c) The PDB shall be able to download data to optical disks of a format to be selected for purposes of transfer to archive. [L]

4.6.4.2.10 Storage Allocation

a) The PDB shall allow an operator to allocate a specified percentage of disk space on line for a particular data type, and a contingency work area. [L]

b) The PDB shall store at least 14 Gbytes of science and mission operations data in primary storage for the Development delivery. [L]

c) The PDB shall store at least 3 Gbytes of science telemetry data in primary storage for the Launch delivery. [L]

d) The PDB shall store at least 11 Gbytes of missions operations data in primary storage for the Launch delivery. [L]

e) The PDB shall allow an operator to dynamically re-allocate a Project-specified allotment of primary storage space.

f) The PDB shall allow for secondary storage of at least 283 GBytes, not including the required backup copy of the PDB. [E]

g) The PDB design shall accommodate expansion of PDB storage capacity to accommodate new requirements. [E]

4.6.4.3 Data Products Software Requirements

4.6.4.3.1 E kernel Software

4.6.4.3.1.1 Input Requirements

a) The E kernel software shall accept the Stored Sequence File from PSS.

b) The E kernel software shall accept the Command Report File from DAC.

c) The E kernel software shall accept ASCII files containing Science team "notebook" events.

d) The E kernel software shall accept Status Reports (ASCII files) describing significant events on board the spacecraft.

e) The E kernel software shall accept Status Reports (ASCII files) detailing significant events of the end-to-end ground data system.

f) The E kernel software shall accept controls, including those necessary to designate start and stop times, input stream and output file storage.

g) The E kernel software shall accept the DSN keyword file.

h) The E kernel software shall accept the SEQTRAN runlog and the Predicted Events File (PEF).

i) The E kernel software shall accept the Real Time Interactive and Noninteractive Command Files and GCMD File information (this info shall detail the time period when the GCMD may be sent).

j) The E kernel software shall accept the SCLK/SCET correlation file.

k) The E kernel software shall accept the Sequence of Events file (SOE).

4.6.4.3.1.2 Processing Requirements

a) The E kernel software shall sort and merge files to create the E logical kernel, which will be a collection of physical files.

b) The E kernel software shall allow sorting and merging of component files by instrument and time.

4.6.4.3.1.3 Output Requirements

a) The E kernel software shall produce a time-ordered Predict E kernel that shall contain the commands in the stored sequence from the PSE. This includes the commands for the MGS spacecraft for a one-week period.

b) The E kernel software shall produce a time-ordered Final E kernel that shall contain the commands that were sent to the spacecraft, including real time commands and the time at which they were sent to the spacecraft. The Final E kernel shall also contain a report of significant events on the spacecraft or in the GDS relating to instrument data interpretation.

c) The final E kernel shall contain "notebook" events from the Science teams describing scientific rationale for each observing sequence or scenario.

d) The E kernel software shall produce a Daily Detailed Command Report (DDCR). This report will be produced five days per week and will contain the commands that were sent to the spacecraft since the previous DDCR was generated.

e) The E kernel software shall produce a list of the information that applies to a particular instrument for a specified period of time.

4.6.4.3.2 Validate, Recall and Merge (VRM) S/W

The VRM software shall, validate the telemetry and monitor data from a particular time period, provide a list of gaps, and merge replayed data. **This software is available to aid in the PDB administration task described in section 3.6.2 of Volume 3. After June 1997, MGS operations will rely on the DSN's advanced delivery system for complete data transfer from the stations to the PDB; therefore recall and merge will not be done as a project-level process after that date. The VRM tool will continue to be available as a validation aid**

4.6.4.3.2.1 Database Analysis Requirements (MOSO) [E]

a) The VRM software shall read the telemetry database within a time range input by the user. Time range may be set using SCLK, ERT or SCET.

b) The VRM software shall create a tabular report listing telemetry gaps by individual engineering and science packet types. The report shall show the time of the last packet before each gap and that of the first packet after each gap.

c) The gap report shall include the total number of packets loaded by type.

d) The gap report shall include an estimate of the number of packets missing in each identified gap using the packet SCLK delta as the metric.

4.6.4.3.2.2 Input Requirements

a) The VRM software shall accept telemetry and monitor data from a specified time period.

b) The VRM software shall accept and respond to operator controls designating the beginning and ending time for the validated data.

4.6.4.3.2.3 Processing

a) The VRM software shall validate input data. This process shall check for gaps in the data stream and anomalies in the headers.

b) The VRM software shall generate a record containing the data specified by the operator controls as inputs.

c) The VRM software shall generate an error report of this process.

d) The VRM process shall produce a list of the gaps for which data could be recalled and merged to meet QQC standards.

4.6.4.3.2.4 Output Requirements

The VRM software shall produce validated, merged telemetry and monitor data that mission requirements are met.

4.6.4.3.3 SCLK/SCET Coefficients File Generation Software

Provides the ability to generate the file of coefficients which determine the relationship between the spacecraft clock time (SCLK), Earth Receive Time (ERT), spacecraft event time (SCET) and orbit number.

4.6.4.3.3.1 Input Requirements

a) This software shall accept and process OWLT files containing downlink one-way light time versus earth-received time.

b) This software shall accept MGS telemetry data.

c) This software shall accept manual controls designating the input stream and identification of output file.

d) This software shall accept manual controls to delete points from the stored set of SCLK/SCET correlations and specify the SCET or SCLK value at which a new correlation is to be generated.

e) This software shall accept and process controls to terminate a time correlation task.

f) This S/W shall accept definitions of relevant S/C-internal time delays.

4.6.4.3.3.2 Processing Requirements

a) This software shall generate and save to disk a file that contains the relationship of the SCLK and SCET.

b) This software shall generate and save to disk a file which compares the actual and predicted SCLK/SCET relationships.

c) This software shall update the SCLK/SCET coefficient by performing the least squares fit of SCLK versus SCET.

d) This software shall generate a discrepancy report containing error and out of tolerance messages which are used to assess the quality of the program output and to point to the source of any program input errors. This includes a plot of the difference between predicted and actual correlations.

e) This software shall convert SCLK to SCET or ERT by querying the SCLK/SCET coefficient file for the appropriate conversion coefficients.

f) This software shall convert SCET to SCLK or ERT by querying the SCET/SCLK coefficient file for the appropriate conversion coefficients.

g) This software shall convert ERT to SCLK or SCET or orbit number.

4.6.4.3.3.3 Output Requirements

a) A file that contains the relationship of the SCLK and SCET.

b) A file which compares the actual and predicted SCLK/SCET relationships.

c) A discrepancy report containing error and out of tolerance messages.

d) A plot of the difference between predicted and actual correlations.

e) A file that contains the relationship of ERT to SCLK, SCET and orbit number.

4.6.4.4 User Tools Software Requirements

This software provides commonly needed utilities for the users of the DSR. The requirements are:

a) A utility shall be provided for the user which will create an SFDU envelope for the user's text and binary data, based on inputs provided by the user. [D]

b) A utility shall be provided for the user which will remove the SFDU envelope from the data. [D]

c) The data shall not be altered from its original form if it is processed by both the SFDU creation utility and the SFDU removal utility. [D]

d) A utility shall be provided for the user that allows E-mail to be converted into a data product and stored in the PDB. [L]

e) A editing capability shall be provided for the user.

1) The editor shall be capable of processing the inputs to the E kernel. [L]

2) The editor shall be capable of processing E-mail. [L]

3) The editor shall be capable of processing inputs to the PDB. [D]

4) The editor shall be capable of processing data sent between workstations using the file transfer function. [D]

5) The editor shall be capable of being used for report generation. [L]

f) SFDU tools shall provide a capability to interactively specify values for selected subset of attributes for a particular object. [L]

g) SFDU tools shall provide a capability to create and store a set of values which correlate with a selected subset of the attributes for a particular object. [L]

4.6.5 Performance, Recovery and Availability Requirements

The following paragraphs describe performance requirements that are levied against the DSR. The requirements for this software are placed solely on (MOSO) [L] except where noted.

4.6.5.1 DSR Downlink Performance Requirements

a) The DSR shall accept, process and store science and engineering data on the PDB within five minutes, nominally, (and twelve hours as a worst case) after the data is acquired by the DSCC. The worst case suballocation is as follows:
   a) DSN: 2 hours;
   b) MOSO: 10 hours.

b) The DSR shall validate continuity of data packets within thirty minutes nominally (and within 12 hours as a worst case) after the data are loaded to the PDB.

c) The DSR shall process seven days worth of archival experiment data (i.e., Instrument Packet Data and SPICE) records in five 8-hour work days.

d) The DSR shall produce, store and catalog on the PDB the Final E kernel within two weeks after the science data is received from the DSN and TBD.

e) The DSR shall load, process, store and transmit the data from all tracking passes and all replays that are necessary to fill gaps to Project specifications within seven days.

f) The DSR shall be able to load, process and store engineering data at real-time rates of 10 bps (emergency mode), 250 bps (mission mode) and 2 Kbps (engineering and dwell modes). [D]

g) The DSR shall be able to load, process and store telemetry data streams of up to 74 Kbps, including up to 8 Kbps of engineering telemetry. [D]

h) The DSR shall be able to load, process and store radio science open-loop data at rates up to 20 Kbps for periods up to 1 hour.

i) The DSR shall be able to load, process and store Navigation data at 15 bps sampled every 60 seconds during cruise.

j) The DSR shall be able to load, process and store Radio Science closed-loop data at 90 bps sampled every 10 seconds during cruise.

4.6.5.2 General DSR System Requirement

The DSR shall provide an electronic file transfer capability between the PDB and workstations on the MGS LAN and between individual Project workstations that satisfy the following requirements:

a) An effective rate of 3 Mbits per second of data.

b) A bit error rate no greater than 1E-10.

c) a packet error rate no greater than 1E-4.

d) Establish the communications link and allow an authorized user access to their data products within 20 seconds.

e) Invoke file transfer program within 5 seconds.

f) Identify/prepare file for transfer within 5 seconds.

g) Transfer 100 Mbytes file within 4 minutes.

4.6.5.3 PDB Performance Requirements

a) The PDB shall be accessible 24 hours per day, 7 days per week, with the exception of a five percent allocation for service. File transfers and queries shall be possible at all times that the PDB is accessible. (MOSO)[D]

b) The PDB shall begin transmitting requested data to a PI or Engineering Analyst within 2 minutes maximum, and 5 seconds nominally, of Data or Catalog Request time for data stored online, and 30 minutes maximum, and 10 minutes nominally, for data stored offline measured from the time the request is entered in the PI/TL/IDS or Engineering Analyst's workstation to the time the requested data begins arriving at the workstation. (MOSO)[L]

c) The PDB shall be able to load data from at least twelve 56 Kbps lines running full up concurrently while downloading data to removable media and accepting data input via removable media. (MOSO)[L]

d) The PDB shall be able to accept data inputs and outputs concurrently from all the Subsystems of the MGS GDS. (MOSO)[L]

e) The DSR shall ensure that, with the exception of a catastrophic failure, no data are permanently lost from the Project Data Base because of MGDS system failure. (MOSO)[L]

f) The PDB catalog shall recover from failures (loss of user access to the catalog) in less than 10 minutes nominally (75% of the time), and 2 hours as worst case (99% of the time). (MOSO)[L]

g) The PDB shall catalog MGS data products within 1 minute, nominally (and 5 minutes as a worst case) after the data products are loaded on, or moved within, the PDB. (MOSO)[L]

4.6.6 Interface Requirements

DSR internal interfaces are provided in Table 4.6.3. DSR external interfaces are provided in Appendices A.

Table 4.6.3 DSR Internal Interfaces

a) DSN to MGDS Acquisition and PDB

Digital RS
MON blocks
TLM blocks
Radiometric ODF
Tracking ATDF
Timing, Polar Motion and Tracking Calibration File
Simulated TLM data
Simulated RS
Simulated MON data
Simulated CMD data
IDR - DACE024 [TBD]

b) MGDS Acquisition to Data Products (through PDB)

Simulated MON data
Simulated TLM data
MON data
TLM data
QQC data

c) SIM to DSN

Simulated TLM data - DACE023

d) SIM to MGDS Acquisition

Simulated MON data
Simulated TLM data

APPENDIX A: MOS GDS Interfaces

In this section, GDS interfaces are sorted by sending and receiving subsystem.

Notes:

1) (DSR) (in parenthesis), indicates that the interface involves a PDB-resident file.

2) DSR (not in parenthesis), indicates that the DSR subsystem provides functional capability to either create or process the file content.

3) MMC stands for Multimission Control. This pseudo subsystem designator is used in cases where the sending or receiving entity is not a functional component of the GDS.

4) The parenthetical (r) indicates a file is received for review only - it is not required by the receiving subsystem.

MGS Software Interface List

I/F ID	I/F TITLE	Cog Engineer	Generating Subsystem(s)	Receiving Subsystem(s)	Phases
DACE001	DSN Viewperiod File		DAC	EAS (DSR) NAS PSS	D L E
DACE002	Command Database		**EAS**	DAC (DSR) PSS EAS	D L E
DACE003	DSN Allocation File		DAC	(DSR) NAS PSS	D L E
DACE004	Archival Tracking Data File (ATDF)		DAC	(DSR) SSS NAS	L E
DACE005	Orbit Data File (ODF)	P.Esposito	DAC	(DSR) SSS NAS	L E
DACE006	Media Calib Data File		DAC	SSS NAS (DSR)	L E
DACE007	Time & Polar Motion File		DAC	(DSR) SSS NAS	L E
DACE009	Tracking Station Locations and Err File		DAC	(DSR) SSS	L E
DACE011	Raw DSN Monitor Blocks		DAC	DAC (DSR) SSS NAS EAS	L E
DACE012	S/C Channelized Engr Data		DAC	(DSR) EAS SSS DAC	D L E
DACE013	Channelized Monitor Data		DAC	DAC NAS EAS (DSR) SSS	L E
DACE014	Telecom Performance Predictions		DAC	EAS	L E
DACE016	Engr Channel Parameter Table		**EAS**	(DSR) DAC	D L E
DACE017	Channel Conversion Language (CCL) File		**EAS**	(DSR) DAC	D L E
DACE020	Command Report [TBD]		DAC	EAS DSR	
DACE022	Weather Data		DAC	(DSR) SSS	L E
DACE025	DSN Formatted Command File (CMD_DSN, aka GCMD)		DAC	(DSR) PSS DAC	L E

MGS Software Interface List

I/F ID	I/F TITLE	Cog Engineer	Generating Subsystem(s)	Receiving Subsystem(s)	Phases
DACE029	Decom Map		**EAS**	DAC (DSR) SSS	D L E
DACE031	DSN-GIF MGDS Gateway		DAC	DAC	D L E
DACE034	QQC Records		DAC	SSS DAC (DSR)	D L E
DACE037	ECDR		DAC	EAS SSS	D L E
DACE040	S/C ENG Telemetry Packet Data Record		DAC	EAS SSS (DSR)	D L E
DACE041	Command Transmission Protocol		DAC	DAC	L E
DACE042	Command Translation Table	DAC	DAC EAS PSS	(DSR)	D L E
DACE043	Raw Telemetry Frames		DAC	DAC SSS	D L E
DACE044	Radio Science Open Loop SCP & SSI Data		DAC	SSS (DSR)	L E
DACE045	Radio Science Open Loop SCP Data Decom Map		DAC	(DSR)	L E
DACE046	Radio Science Open Loop Data		DAC	SPA SSS (DSR) PDS(via RS Team)	L E
DACE047	ASCII S/C Tracking Data File (ODF) (TRK 2-27)	P.Esposito	DAC	NAS	L E
DACE048	Browser Config. Files		DAC	SSS, DAC, (DSR)	D L E
DACE049	DMD TDL File		DAC	SSS, DAC, (DSR)	D L E
DSR004	MAG/ER Packet Data Record		DAC	SPA, SSS	L E

MGS Software Interface List

I/F ID	I/F TITLE	Cog Engineer	Generating Subsystem(s)	Receiving Subsystem(s)	Phases
DSR005	TES Packet Data Record		DAC	SSS SPA	L E
DSR006	MOC Packet Data Record		DAC	SSS SPA	L E
DSR007	MOLA PacketData Record		DAC	SSS SPA	L E
DSR011	Raw Data Query Results File		DSR	EAS SSS	L E
DSR012	QQC Summary Report File		DSR	EAS SSS (DSR)	L E
DSR013	Database Catalog Search Results File		DSR	EAS SSS	L E
DSR015	PDB Objects and Attributes		ALL	DSR	D L E
DSR017	Spacecraft Clock Coefficient File		DSR	EAS PSS SSS DAC (DSR)	D L E
EAS003	Angular Momentum Desaturation	P.Esposito	EAS	(DSR) NAS	L E
EAS006	SCT System Report File	TBD	EAS	SSS NAS (DSR)	L E
EAS008	Maneuver Performance Data File	P.Esposito	EAS	NAS (DSR)	D L E
EAS011	NAV Engr Information File	P.Esposito	EAS	NAS (DSR)	L E
EAS014	Maneuver Implementation File	P.Esposito	EAS	(DSR) NAS	D L E
EAS017	Stream Data Extract Command Line Input IF		EAS SSS	DSR	L E

MGS Software Interface List

I/F ID	I/F TITLE	Cog Engineer	Generating Subsystem(s)	Receiving Subsystem(s)	Phases
EAS018	Database Catalog Command Line Input I/F		EAS SSS	DSR	L E
LUE001	Launch Polynomials	P.Esposito	LUE	DAC NAS	L
LUE002	Predicted Injection Error Matrix	P.Esposito	LUE	NAS	D
LUE003	Injection Initial Conditions		LUE	DAC NAS	L
MMC004	GDS Status Report	F.Hammer	TBD	TBD (DSR)	D L E
NAE001	Station Polynomial File	P.Esposito	NAS	EAS DAC (DSR)	L E
NAE002	Light Time File	P.Esposito	NAS	DAC SSS EAS (DSR) PSS	D L E
NAE003	Orbit Propagation & Timing Geometry File	P.Esposito	NAS	(DSR) PSS SSS EAS	D L E
NAE004	Planet Ephemeris & Errors File	P.Esposito	NAS	NAS (DSR) DAC	D L E
NAE005	Satellite Ephemeris and Errors File	P.Esposito	NAS	NAS (DSR)	E
NAE006	Maneuver Profile File	P.Esposito	NAS	EAS (DSR)	D L E
NAE007	Planetary Constants Kernel File	P.Esposito	NAS	(DSR) EAS SSS	L E
NAE008	Astrodynamic Constants & Init Cond File	P.Esposito	NAS	SSS (DSR) EAS	L E
NAE009	S/C Ephemeris File	P.Esposito	NAS	DAC	L E
NAE011	S&P Kernels	P.Esposito	NAS	EAS SSS (DSR)	L E

MGS Software Interface List

I/F ID	I/F TITLE	Cog Engineer	Generating Subsystem(s)	Receiving Subsystem(s)	Phases
PSE001	Predicted Events File	SEQ Cog	PSS	STL (DSR) SSS NAS(r) EAS PSS	D L E
PSE002	Sequence of Events File	**[TBD]**	**DAC**	NAS(r) EAS SSS(r) (DSR)	L E
PSE003	Space Flight Operations Schedule File	[TBD]	DAC	NAS(r) EAS SSS(r) (DSR)	L E
PSE004	Spacecraft Command Message File	SEQ Cog E	PSS	STL DAC (DSR)	D L E
PSE005	DSN Keyword File	[TBD]	DAC	(DSR) DAC PSS	D L E
PSE008	Cumulative Memory Map	SEQ Cog E	PSS	EAS (DSR)	D L E
PSE010	S/C Activity Sequence File	SEQ Cog E	PSS	PSS EAS (DSR) SSS	D L E
PSE011	S/C Sequence File	SEQ Cog E	PSS	PSS (DSR)	D L E
PSE013	SEQTRAN Desired Memory Word File	SEQ Cog E	PSS	EAS (DSR)	D L E
PSE014	Spacecraft Checkout Station Command Data File		PSS	Spacecraft System	D L
SSE001	I-Kernel		SSS	(DSR) SPA SSS	L E
SSE004	Instrument Status Report		SSS	EAS (DSR)	L E
SSE005	Instrument Power Profile	B.Brooks	SSS	PSS (DSR) EAS	L E

MGS Software Interface List

I/F ID	I/F TITLE	Cog Engineer	Generating Subsystem(s)	Receiving Subsystem(s)	Phases
DSR001	E-KERNEL		DSR	MMC DAC SSS	L E
DSR016	Inputs to E-KERNEL		PSS, SSS DAC, [EAS]	DSR	L E
DSR018	**Telemetry Dictionary**	**O. Short**	**SCT**	**DAC, SSS, PSS, EAS, NAS**	**L**
DSR019	**Command Dictionary**	**O. Short**	**SCT**	**DAC, SSS, PSS, EAS, NAS**	**L**
DSR020	**Block Dictionary**	**J. Neuman**	**SCT**	**DAC, SSS, PSS, EAS, NAS**	**L**
DSR021	**Flight Rules**	**J. Neuman**	**SCT**	**DAC, SSS, PSS, EAS, NAS**	**L**
EAS007	C-KERNEL (Reconstructed)		EAS	SSS NAS EAS (DSR)	E
NAE015	Solar Coronal Model Correction (memorandum)	P.Esposito	DAC	NAS	L E
VTL002	STL Sequence Output		STL-TBD	EAS	
VTL003	STL Miscomp. Events		STL-TBD	EAS	
VTL004	STL Memeory Dump		STL-TBD	EAS	
VTL005	STL Sim Runlog		STL-TBD	EAS	

Note: The parenthetical (r) indicates a file is received for review only - it is not required by the receiving subsystem.

APPENDIX B: PSS Terms and Definitions

The following abbreviations and terms are used in Section 4.2:

SOA - Sequence of Activities. A generic term used to describe the pre-planned activities (past, present and future, SASF) to be accomplished by the spacecraft and ground systems. This may include individual ground and spacecraft commands and macro calls, miscellaneous notes, and supporting documentation.

SASF - Spacecraft Activity Sequence File. A file within the sequence data set containing the various Miscellaneous Notes, ground and spacecraft macro calls, command stems and fields and rationale pertaining to the activity to be performed on the ground or spacecraft. This term applies to activity requests from both an individual user and the merged requests from a set of users.

SSF - Spacecraft Command File. A file within the sequence data set containing spacecraft macro calls, and other commands required to actually control the action of the spacecraft and ground systems. This is basically a 'human readable' form of the binary file transmitted to the spacecraft and used on the ground. It is generated by running an SASF through a transformation which translates the ground-based macro calls into the appropriate spacecraft and ground commands.

PEF - Predicted Events File. A file within the sequence data set containing the same information as the SSF, plus a software mimicry of certain S/C system-level macro calls. This is a software mirror of what the ground and S/C are supposed to do.

SCMF - Spacecraft Command Message File. Contains spacecraft-understandable commands (not including transmission-related overhead, such as sync bits, et cetera). Typically an assembly-language representation of the requested command(s).

Sequence Data Set - The consolidated sequence data used by the PSSsoftware. This is basically a data base containing the command stems, fields, time, names, notes, ad infinitum, required by the PSSto generate the sequence listings, including the SASF, PEF, and SSF, and SCMF.

SCET - Spacecraft Event Time. The UTC time of a spacecraft event.

SCLK - Spacecraft Clock. The time convention used onboard

ERT - Earth Receive Time. The UTC time of a spacecraft event as observed at a DSS. For realtime telemetry, this is a one-way-light-time after the SCET. Often refers to the time at which a particular set of data was (or would be) received at the ground station after being transmitted from or occurring on the spacecraft.

TRM - Transmit Time. The UTC at which a set of data are radiated from a ground station. The spacecraft receives the data a one-way-light-time later.

Stored Sequence Command - A command processed through the Planning and Sequencing Subsystem as part of a 28-day sequence to be loaded into the S/C C&DH.

Non-Stored Command - A command processed through the PSS separate from stored sequence commands. The command may be destined for any spacecraft or payload subsystem, and may be interactive or non-interactive.